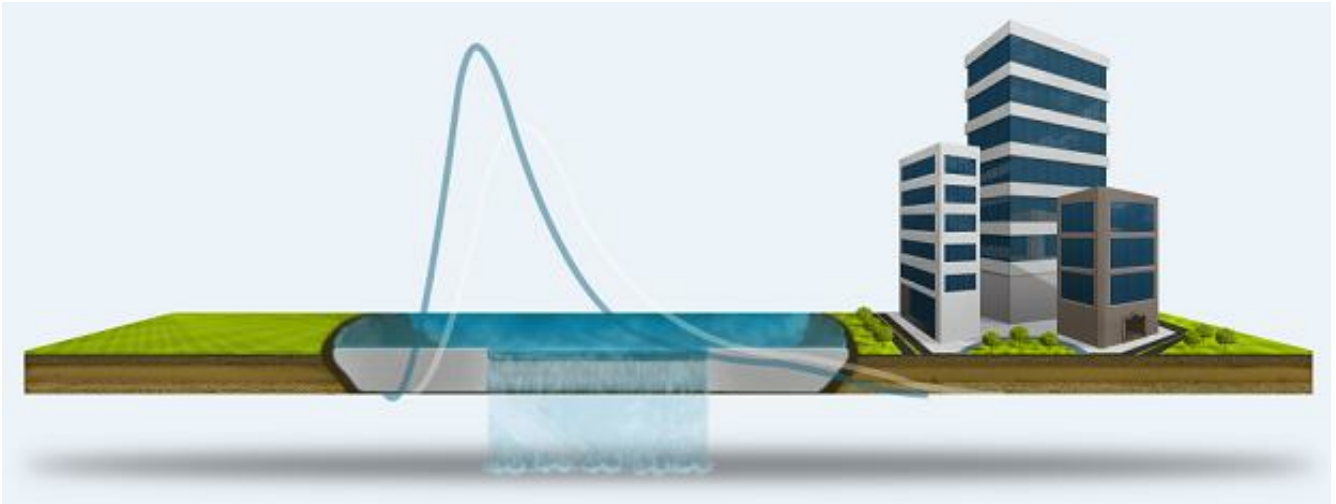


Hydrology Studio

User's Guide



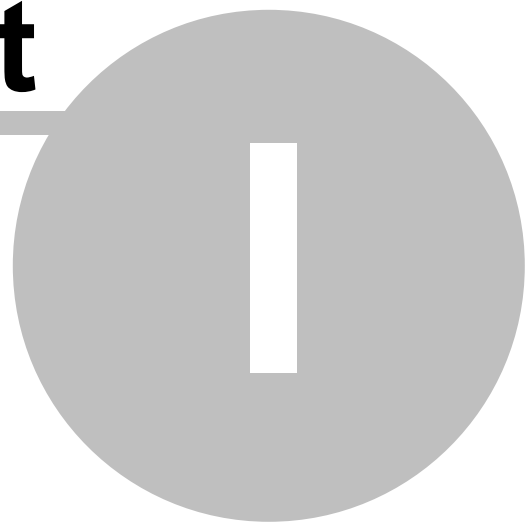
© 2014 Hydrology Studio

Table of Contents

Foreword	0
Part I Introduction	5
1 Installing and Activating.....	6
2 Getting Updates.....	7
3 About This Guide.....	7
Part II Overview	10
1 User Interface.....	11
Basin Model Tab	12
Table Tab	14
Charts Tab	14
Part III Quick Start Tutorials	18
1 Basic Watershed Modeling.....	19
Adding Data & Computing	23
Batch Computing.....	26
2 Pre- and Post-development Modeling.....	27
Create Pre and Post Hydrographs	28
Design Detention Pond	31
Estimate Storage.....	33
Create Pond.....	34
Add Outlets.....	37
Perform Pond Routing	42
3 Getting Output.....	44
Exporting	46
Part IV Basic Working Procedures	48
1 Setting Up Rainfall.....	48
IDF Curves	49
Using Rainfall Map Data	51
Enter Points from Existing Curves	53
Known Equation Coefficients.....	55
IDF Correction Factors	57
Precipitation & Events	58
Importing Precipitation.....	60
Design Storms	62
Custom Design Storms	63
Importing Design Storms.....	65
2 Adding Runoff Hydrographs.....	67
SCS Hydrographs	68
Rational Method Hydrographs	69
Tc by TR55	71
Adding Hydrographs Manually	72
3 Adding Junctions.....	74

4	Routing Through Channels.....	75
5	Creating Detention Ponds.....	78
	Step 2 - Create Pond	79
	Contours.....	81
	Trapezoid.....	83
	Manual Storage.....	85
	UG Chambers.....	86
	Surface Charts.....	88
	Step 3 - Add Outlets	89
	Stage vs. Q Chart.....	91
	Using Trial Route Feature.....	92
6	Routing Through Detention Ponds.....	98
	Interconnected Pond Routing	100
7	Diverting Hydrographs.....	101
8	Batch Run.....	103
9	Project Settings.....	104
10	Editing Your Model.....	105
11	Printing Reports.....	106
Part V	Computational Methods	110
1	SCS Hydrographs.....	110
2	Rational Method Hydrographs.....	114
3	Time of Concentration.....	115
4	Combining Hydrographs.....	118
5	Channel Reach Routing.....	118
6	Stage-Storage.....	120
7	Stage Discharge.....	121
	Exfiltration	125
	Drawdown	125
8	Pond Routings.....	126
Part VI	Useful Tables	128
1	SCS Curve Numbers.....	128
2	Runoff Coefficients.....	129
3	Manning's n-values.....	130
Part VII	End User License Agreement	132
	Index	134

Part



1 Introduction

Welcome and congratulations for choosing the industry's most easy-to-use hydrology software. This state-of-the-art desktop application features comprehensive watershed modeling utilizing the most popular, agency accepted computational methods along with wizard-like detention pond design. All this wrapped around a rich user interface built from the ground up with Windows Presentation Foundation. Say goodbye to those outdated forms-based programs!

If you have landed on this page from an internet search, and would like to visit our website, its home page is www.hydrologystudio.com.

Hydrology Studio was developed primarily for practicing civil and environmental engineers and related professionals involved with urban and rural watershed modeling and detailed detention pond design.

What you can do with Hydrology Studio

- Complex watershed modeling and regional drainage studies
- Simple site designs
- Pre- and post-development studies
- Fast & easy detention pond sizing and design
- Produce professional looking, agency-ready reports that make you look good

Partial List of Technical Features

- Models entire complex watersheds
- Uses SCS/NRCS TR-20, Rational and Modified Rational
- 2,880-point hydrographs for maximum accuracy
- No limits on drainage areas
- Handles up to 100 hydrograph nodes, each with up to 8 return periods at once, for a total of 800 hydrographs!
- Automatic batch run operation for user-defined multiple return periods
- Built-in SCS 6 & 24-hr (including Type IIFla) storms in any time interval
- Built-in Huff Distributions in any time interval, all quartiles
- Up to 10 unique custom design storms can be specified
- Develops synthetic design storms based on IDF curves
- Develops rainfall IDF curves
- Built-in Lag and TR-55 method Tc calculator
- Combines up to 6 hydrographs at once
- Routes hydrographs through channels
- Diverts hydrographs by constant Q, ratio, 1st-flush volume or any pond outlet structure
- Computes outlet flows for detention ponds
- Up to 10 user-definable outlet structures per pond including exfiltration

- Handles multi-stage outlet works
- Storage values can be computed from contour areas, bottom area / side slope or a built-in underground storage calculator with optional stone encasement
- Weirs types include rectangular, Cipoletti, riser, broad crested and v-notch
- Routes hydrographs through wet, dry or interconnected detention ponds
- Much more!

Output Features

Got reports? Check the options you like on comprehensive Report Options menu and Hydrology Studio starts printing easy-to-read numerical reports, including their graphs, for any or all return periods. Includes Print Preview. Batch processing at its best!

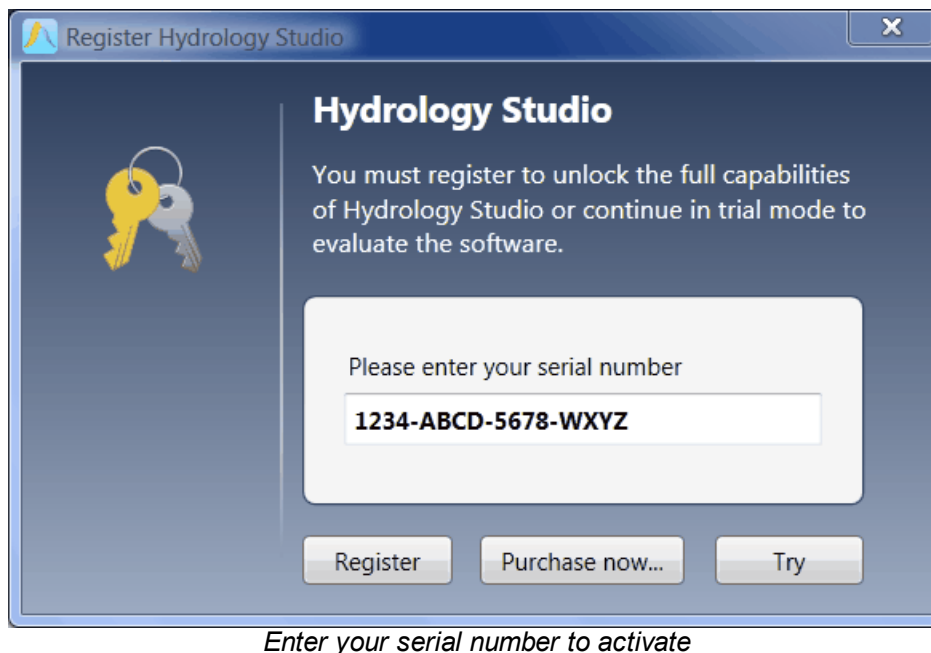
1.1 Installing and Activating

By now you probably have Hydrology Studio installed but just in case you haven't, just follow the purchase/download instructions at the Hydrology Studio website www.hydrologystudio.com. The initial download will contain the free trial version which has no time limit but limited functionality. For example, you won't be able to save project files and most of the reports will be watermarked.

Hydrology Studio uses Microsoft's "Click-once" technology which makes the installation process fast and easy. A desktop icon will be automatically created and will launch the program.

How to Activate Hydrology Studio

Upon launch, Hydrology Studio checks for the registration key. If it is not available, an activation screen appears like the following:



Once the serial number is entered it is stored and you won't be reminded again.

Loose your serial number?

If for some reason your serial number is lost, please visit www.hydrologystudio.com/support for retrieval or email support@hydrologystudio.com

1.2 Getting Updates

Hydrology Studio will automatically check for program updates, revisions and fixes upon each launch. You may choose to "Update" then or "Skip" and wait until a later time. If you choose to skip the update, you will not be prompted again until the next update is released.

1.3 About This Guide

It's the 21st century and desktop software has matured. User interfaces like those of Hydrology Studio are being designed to rely less on help aids like a user manual. The best help system is actually "no help". In other words, the user interface should be intuitive enough so that the user shouldn't have to disengage from their task and read a manual. We like to think Hydrology Studio is one of those programs as it makes good use of tool tips and built-in help illustrations. If at any time, you feel some

important content is missing or could be improved, please send us an email at support@hydrologystudio.com. We would appreciate your feedback.

Rather than document each and every input item in the software, this guide is more task based with "How to" topics. The tutorials in the next section provide a quick introduction to using Hydrology Studio. They are intentionally kept brief so that you can actually start using the program as quickly as possible. The objective is not to teach you every single detail but to familiarize you with the basic principles and the way the program works.

Online Learning Videos and More

As they say, "a picture is worth a thousand words". A library of videos demonstrating the use of Hydrology Studio is being developed on the website at hydrologystudio.com/tutorials/. Topics include basic watershed modeling to detention pond design and everything in between. Please check for new additions regularly as this will hopefully be your primary source for in depth explanations. You'll probably learn some lessons on hydrology & hydraulics along the way.

For those who prefer to help themselves or enjoy helping others, an online user forum is also hosted on the website.

Basic Working Procedures

This is where the nuts and bolts of this Hydrology Software are described.

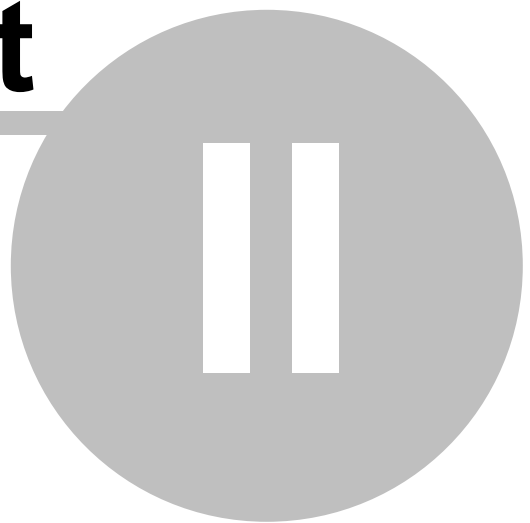
Computational Methods

This section of the guide opens the black box and reveals the inner workings of the program. Methodology, equations and assumptions are each detailed [here](#).

Helpful Tables

The last section contains [tables](#) of SCS Curve Numbers, Runoff Coefficients, Manning's n-values, Orifice & Weir Coefficients.

Part



2 Overview

This section describes the most common basic tasks you will use when working with Hydrology Studio. It is designed as a "How-To" guide and reference manual. Although it is organized roughly in the order that you would perform the tasks you don't need to begin at the beginning and work your way through. Every topic contains comprehensive links to background information and other relevant subjects so you can just pick out the task you need to perform and begin.

How to Begin a New Project



New Project...

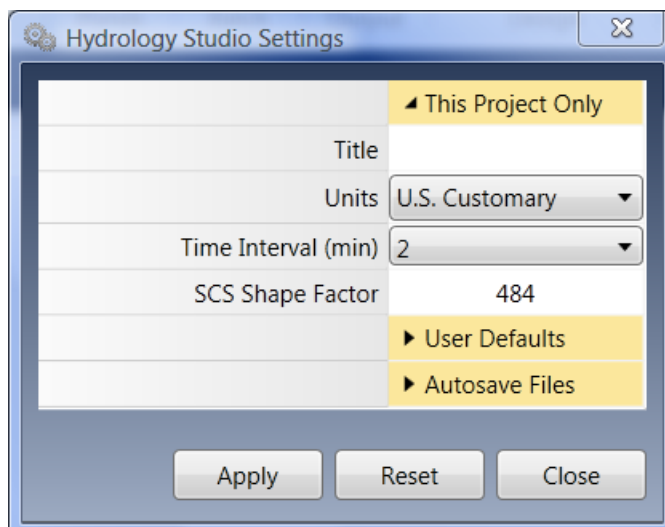
Starting a new project with Hydrology Studio is as easy as creating a new word processing file – you just click on the File menu, select New Project. That's it. In fact, the program is ready to start a new project upon initial launch. In addition, Hydrology Studio reloads the default [rainfall files](#) replacing those which may have been used in a previously loaded project.

Settings



Settings

While it is not necessary, you can open the Settings dialog and specify a Project Title, Time Interval and a variety of other settings. To open, click the **[Settings]** button on the Ribbon Toolbar. These features are discussed in detail in [Project Settings](#).



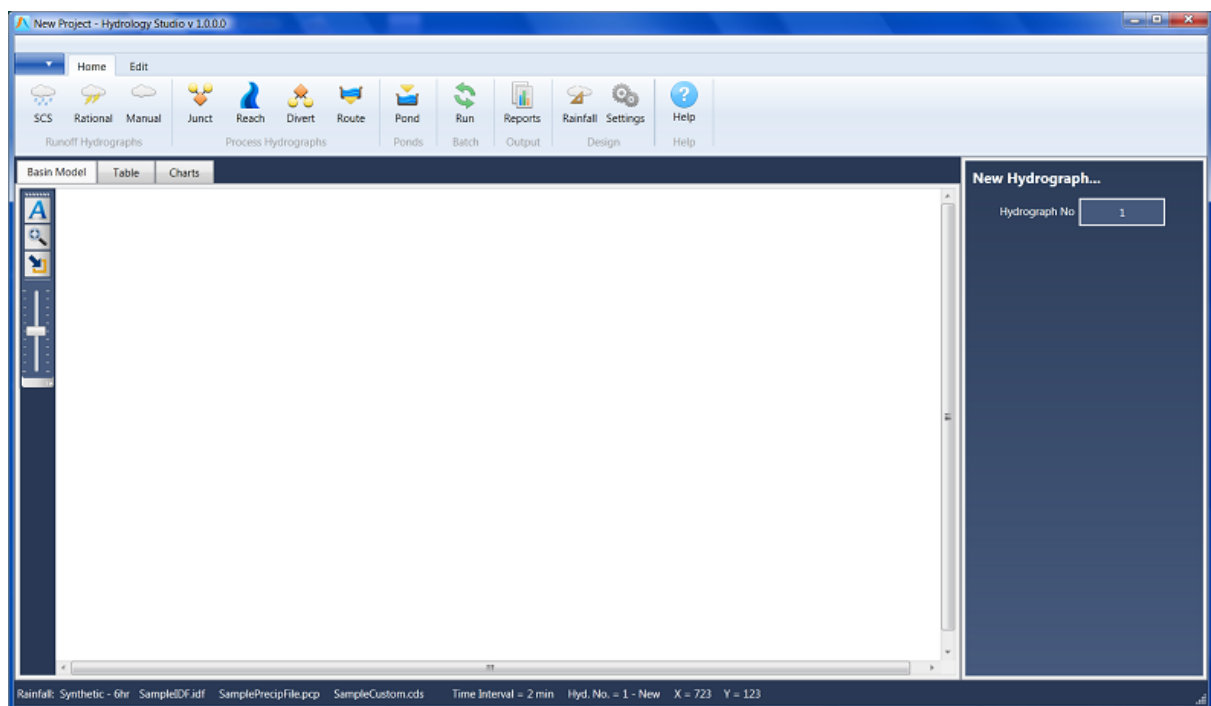
Settings dialog box

2.1 User Interface

Hydrology Studio's main window has four main components:

1. Application Menu
2. Ribbon Toolbar
3. Project Workspace
4. Input Window

Also, at the bottom this screen is a status bar which displays the current rainfall files and Time Interval.



Hydrology Studio features an all-in-one user interface

In general, the workspace (large canvas area) is where you will perform the majority of your tasks. Here you can create and build your watershed basin model, attach or enter data associated with your model, compute and view results. Even print reports.

You'll notice three tabs at the upper left of the canvas:

- **Basin Model** - The area where you visually construct your watershed schematic.
- **Table** - A numerical version of the Basin Model with key computed results added.
- **Charts** - A graphical and numerical combination of the first two tabs.

The **Input Window** is situated on the right. It is always visible and displays the required input fields for any selected hydrograph.

Saving Projects

In terms of printing, saving and opening files, Hydrology Studio works like a word processor. You can save and open your project files to or from any folder at any time as well as print reports. See [Basic Working Procedures](#) for more information.

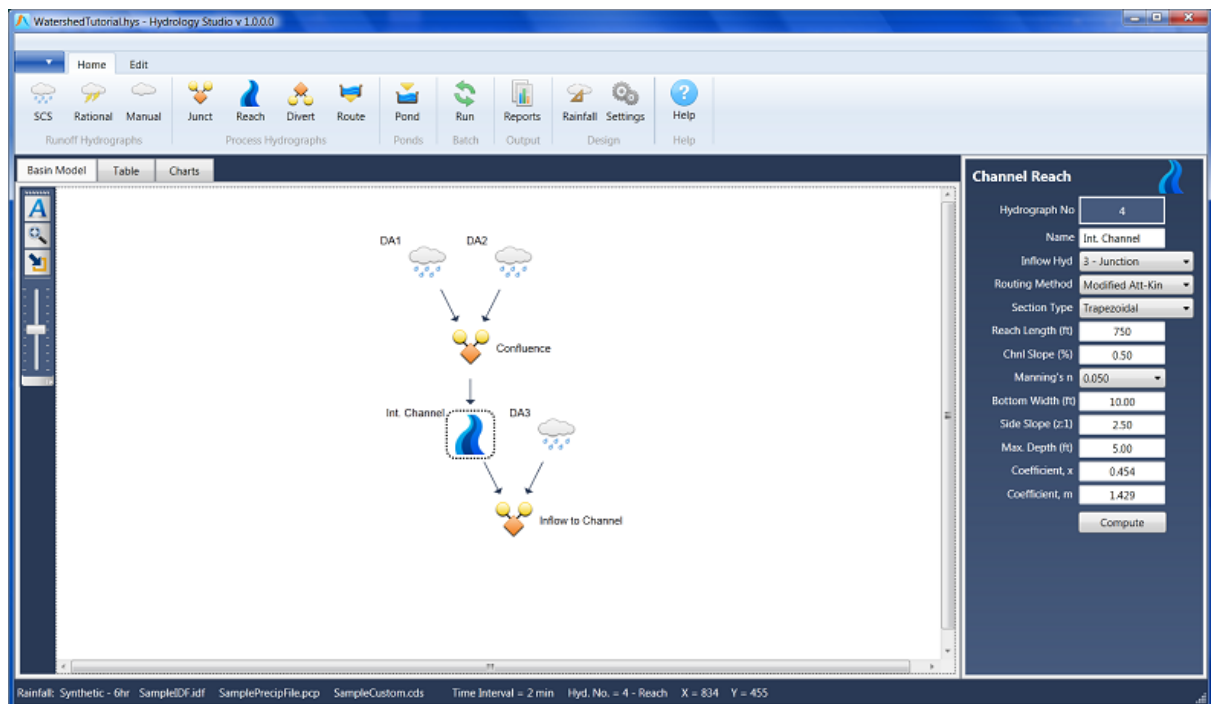
2.1.1 Basin Model Tab

The Basin Model tab is selected by default when Hydrology Studio is launched. While it is not necessary, this is where most projects will begin and is where watershed diagrams are constructed as it provides a good visual of the connectivity of the watershed elements.

Hydrograph icons are automatically placed on the canvas after clicking on one of the Runoff Hydrographs or Process Hydrographs buttons. Once on the canvas you are free to move or reposition them to better match a real world layout. Simply click and drag with your mouse.

You can also reposition groups of icons by holding down the **[shift]** key while dragging. All icons downstream of the selected icon will be included in the move.

Selecting an icon is accomplished by just clicking it. Groups can be selected by clicking while holding down the **[shift]** key or by dragging a rectangle around them.



Basin Model displays your watershed schematic. Click on any hydrograph to select.

Basin Model Toolbar

This tab contains a canvas and a left-side toolbar which is used to toggle on/off the icon labels, redraw the schematic to the program's default layout, load a background map from image files, and to size icons using a slider bar.



Toggles on/off the hydrograph icon labels



Resets the schematic to program's default layout. Not available when background map is used.



Imports or clears a background map from .png, .jpg or .bmp files. All background maps are loaded uniformly to maximize the size. Aspect ratio is preserved.

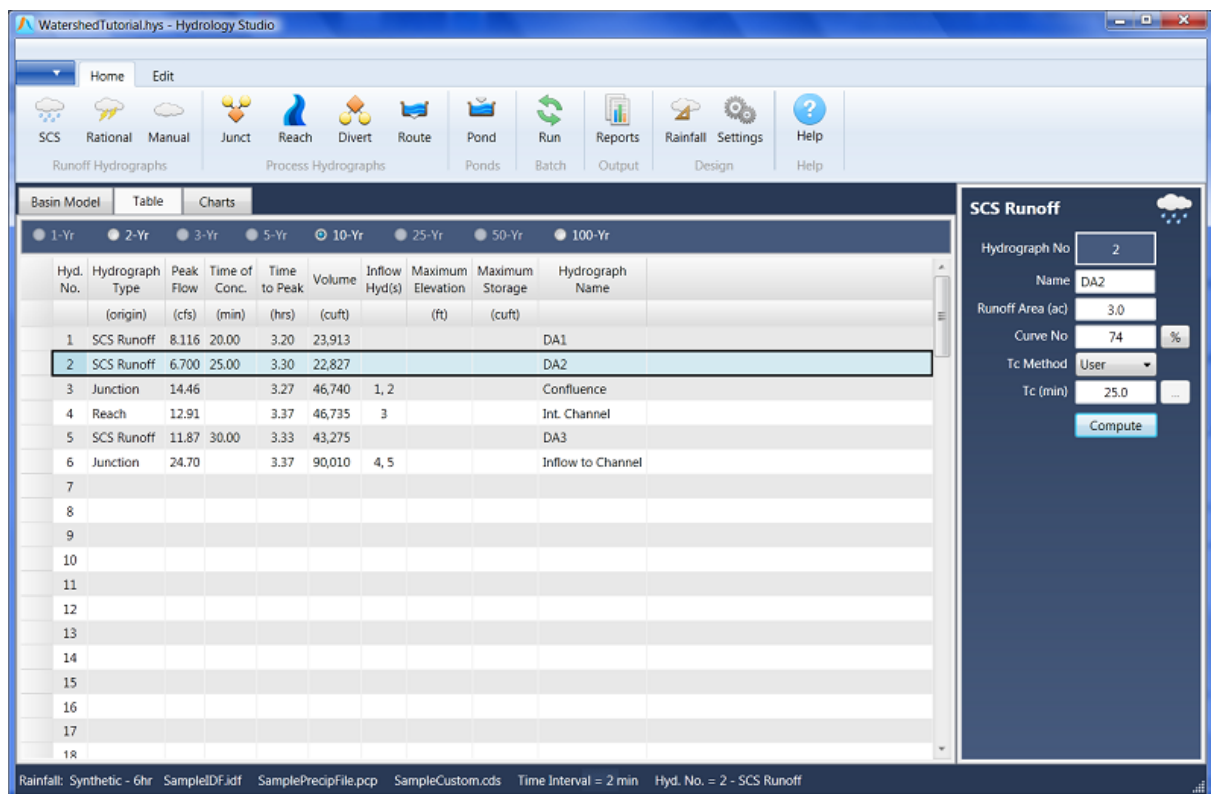


Slider bar changes the size of the icons to better match your drawing scale.

2.1.2 Table Tab

The Table Tab is basically a numerical version of the Basin Model. Here you can get a bird's eye view of select computed results. Hydrographs can be selected by clicking on a row. Multiple selections are made by dragging your mouse or by clicking while holding down the **[shift]** key.

When adding new Runoff Hydrographs, you must first select an empty row.



The Table Tab provides a numerical version of your basin model.

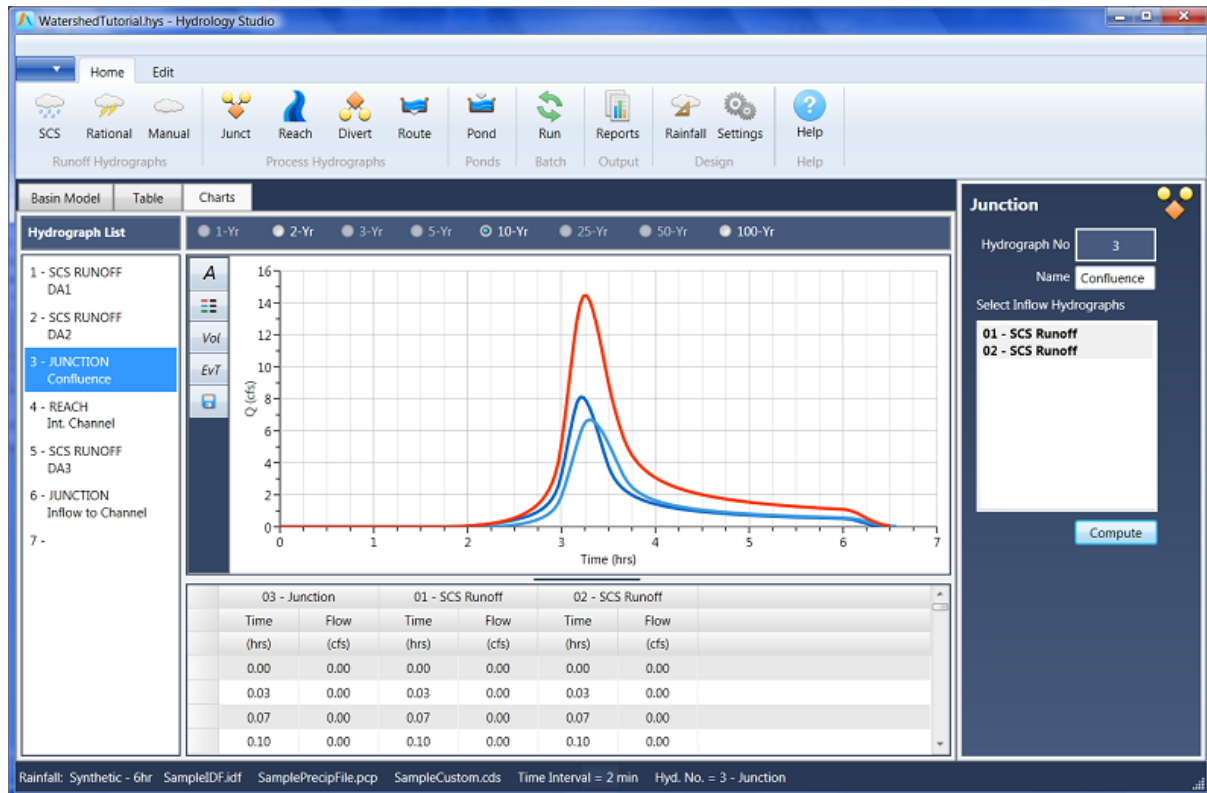


Note the frequency selector bar across the top of the table. Click on any active return return period option to display the corresponding data.

2.1.3 Charts Tab

The Charts Tab turns numbers into pictures as well as offering a table of Time vs. Q. Hydrographs from the Basin Model are listed on the left.

Select a hydrograph to view its corresponding chart. Multiple selections can be made by clicking while holding down the **[Shift]** key. Use the **[Ctrl]** key to select non-adjacent hydrographs.



The Chart Tab offers a graph as well as tabulated Q vs Time table.

The Chart Tab contains a toolbar on the left with the following options:

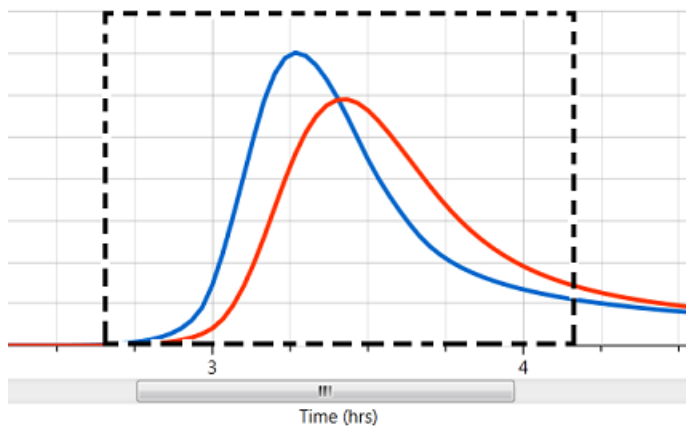
- A** Toggles on/off the Chart Title. Disabled when multiple selections are made.
-  Toggles the chart's legend on/off.
- Vol** Toggles an overlay graph of volume vs. time.
- EvT** Toggles an overlay graph of elevation vs. time. (Pond routing only)
-  Export the displayed chart to an image file as bmp, jpeg or png format.



Note the frequency selector bar across the top of the table. Click on any active return return period option to display the corresponding data.

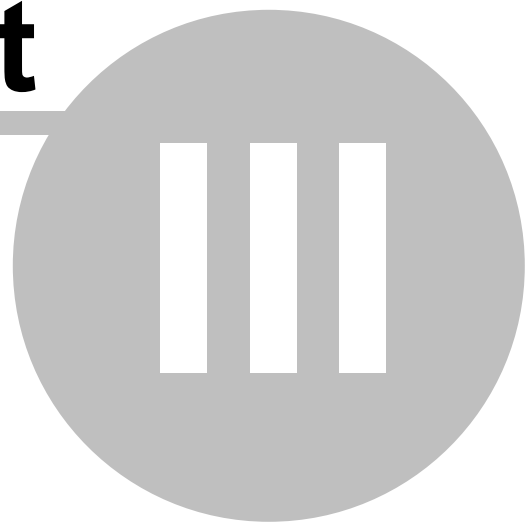
How to Zoom

Any chart in this software can be zoomed by simply dragging a rectangle from the upper left to the lower right of a desired viewport. Double-click the chart to return to full extents.



*Drag a rectangle with your mouse to zoom.
Double-click to return to full extents.*

Part



3 Quick Start Tutorials

The tutorials in this section provide a quick introduction to using Hydrology Studio. They are intentionally kept brief so that you can actually start using the program as quickly as possible. The objective is not to teach you every single detail but to familiarize you with the basic principles and the way the program works.

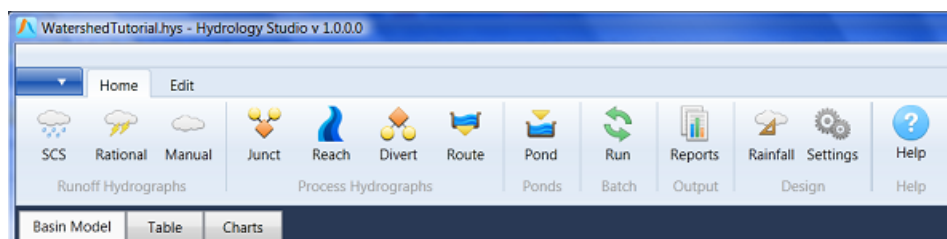
Online Learning Videos and More

As they say, "a picture is worth a thousand words". A library of videos demonstrating the use of Hydrology Studio is being developed on the website at hydrologystudio.com/tutorials/. See these lessons in action!

Hydrology Studio can generate a maximum of 100 hydrographs at once. What's more, each hydrograph contains up to 8 return periods for a grand total of 800. Each hydrograph is identified by a number between 1 and 100. Hydrograph numbers need to increase as you work downstream. The program maintains this numbering system for you and does so in order to properly construct the routing diagram.

Most watershed modeling functions are selected from the Ribbon Toolbar which contains two tabs labeled, Home and Edit. On the Home tab there are three unique sub-tabs for which you can display and process your work.

- **Basin Model** - The area where you visually construct your watershed schematic.
- **Table** - A numerical version of the Basin Model with key computed results added.
- **Charts** - A graphical and numerical combination of the first two tabs.



Basic Procedure

You add hydrographs to your model by simply clicking one of the buttons in either the Runoff Hydrographs group or in the Process Hydrographs group on the **Ribbon Toolbar**. Your model should always start at its upstream end and work downstream. You must first add a Runoff Hydrograph before choosing any from the Process Hydrographs group. Icons representing each hydrograph are automatically inserted on the Basin Model canvas. You are free to drag these icons around to better match the actual site configuration.

Selecting a hydrograph with your mouse pointer (clicking an icon on the canvas, for

example) populates the Input Window on the right. There you can enter or edit the associated input data as well as compute results.

Hydrology Studio is quite flexible in that it allows you to build your entire model schematically before adding any input data or computing anything. Conversely, you can specify the required data items as you go. It's your choice. In addition, you can work with your model from any of the three workspace tabs described above. In addition, you can build more than one model at a time. For example, you can build a separate pre-development model and post-development model in the same project. Models do not need to be connected.

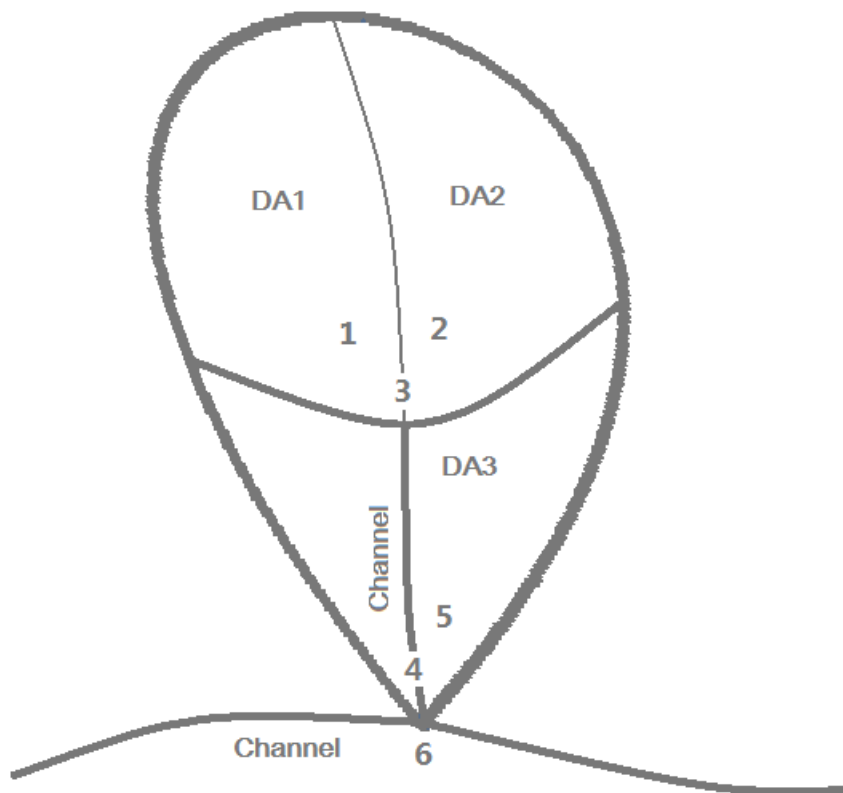
The tutorials in the following sections demonstrate how to create a simple watershed model and how to perform and pre- and post-development analysis.

3.1 Basic Watershed Modeling

A simple watershed has been constructed and shown below and will be the topic of this tutorial. Watershed simulation is accomplished by selecting the appropriate function(s) from the Ribbon Toolbar in the order of the sub-catchment connectivity. You always begin at the uppermost basin and work downstream. This watershed consists of 3 drainage areas and an intermediate channel. Our task here is to develop the downstream hydrograph which outfalls into the lower horizontal channel.

To model the watershed shown below, follow these 5 easy steps:

1. Develop runoff hydrographs for sub-areas "DA1" and "DA2" -- Hydrographs 1 and 2.
2. Add (combine) Hydrographs 1 and 2 to form Hydrograph 3. They converge at the same point.
3. Route Hydrograph 3 through the intermediate channel to create hydrograph 4.
4. Create runoff hydrograph for sub-area "DA3" -- Hydrograph 5.
5. Lastly, add Hydrographs 4 and 5 to create Hydrograph 6.

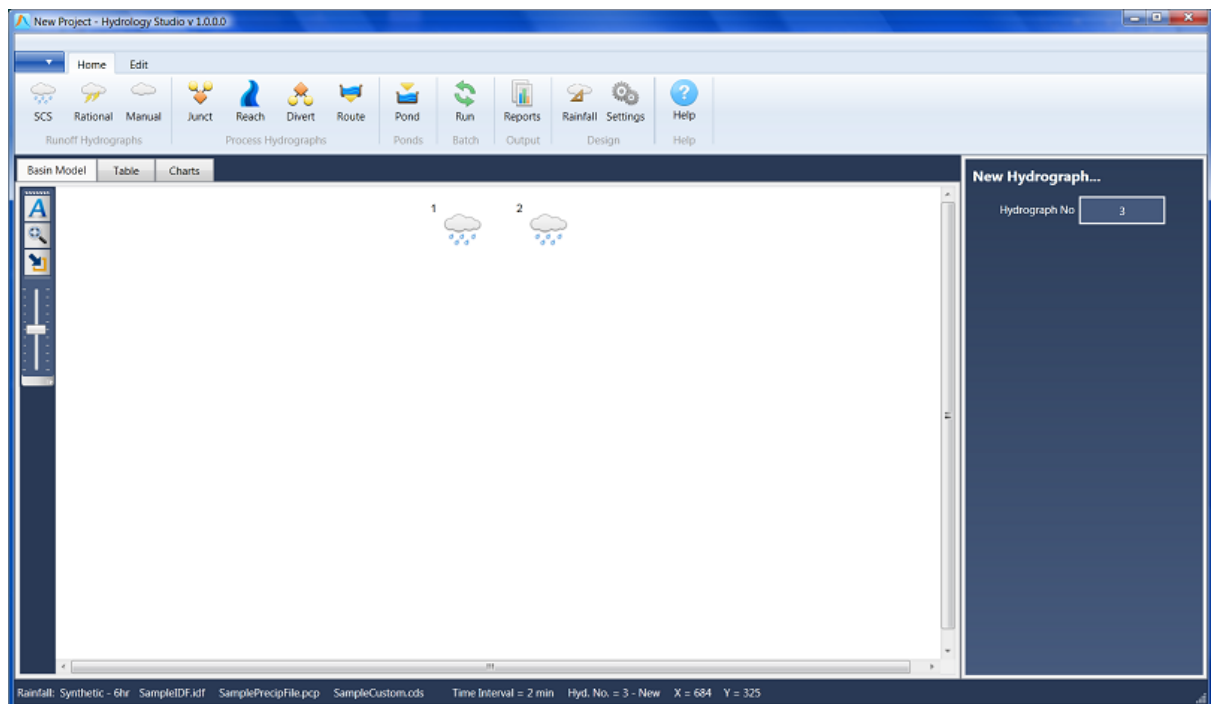


A simple watershed model

Following is a step-by-step procedure working from the “Basin Model” tab. We’ll disregard the input particulars such as drainage areas, CNs and such. This will be covered in more detail in the following sections. This tutorial is simply to illustrate the steps involved in developing a watershed model.

Step 1. Create Runoff Hydrographs for Areas DA1 and DA2

Click your mouse anywhere on the open canvas. Then click the **[SCS]** button on the Ribbon Toolbar. An SCS hydrograph icon will be placed near the top center of your screen. Click the **[SCS]** button again to add the second sub-basin, DA2.



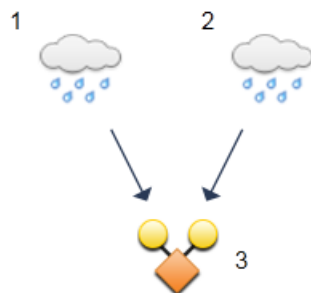
Hydrology Studio updates your model as you add new hydrographs

Step 2. Add the two runoff hydrographs to create a junction.

To add or combine hydrographs, select them first by dragging a rectangle around them with your mouse or alternatively, click on the icons while holding down the **[Shift]** key. Then click the **[Junct]** button on Ribbon Toolbar.



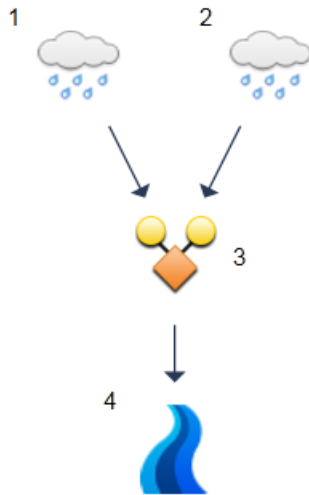
Your model schematic will look like this:



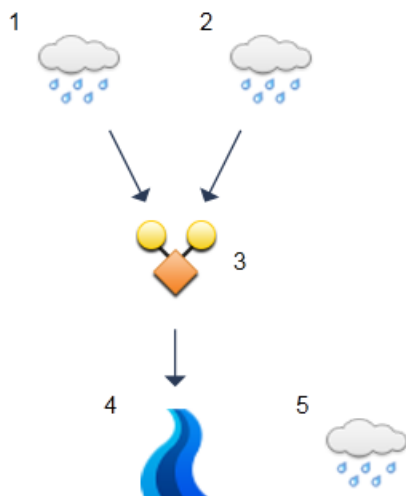
Step 3. Route Hydrograph 3 through the intermediate channel to create

hydrograph 4.

Select Hydrograph 3 and click the **[Reach]** button on the Ribbon Toolbar. The updated canvas will show the following schematic:

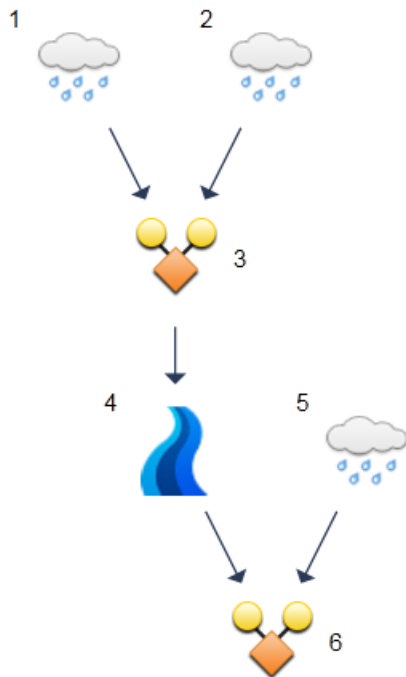
**Step 4. Add runoff hydrograph for sub-basin DA3.**

Simply follow the procedure shown in Step 1, i.e., click the **[SCS]** button. The updated basin model will look like this:

**Step 5. Combine Hydrographs 4 & 5 to create hydrograph 6.**

Select hydrographs 4 & 5 as you did in Step 2. Then click **[Junct]** on the Ribbon

Toolbar. Your final schematic should look like this:



That is all that's needed to build a simple watershed.



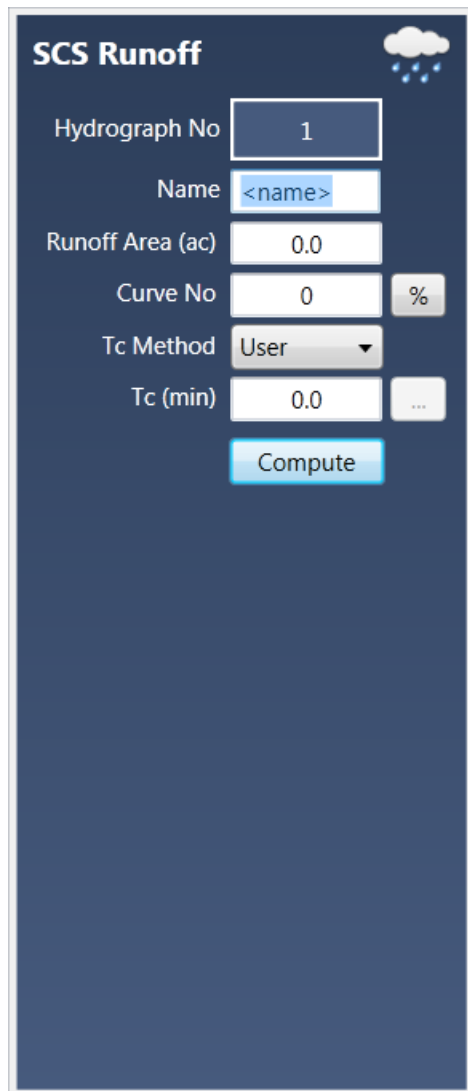
You can reposition any or all of the icons on the canvas to better mimic world conditions by simply dragging them. You can also reposition groups of icons by holding down the [shift] key while dragging.

Of course we haven't added any data to these hydrographs. That is covered in [Adding Data](#).

3.1.1 Adding Data & Computing

One of the great features of Hydrology Studio is its flexibility. You can add data to any hydrograph at any time. In other words, you can build out the entire model as we did in the previous section first and then add data, or you can add the associated data as you work downstream. There's no particular order you need to follow.

As you may have already noticed, when clicking on a hydrograph icon, the Input Window changes to correspond to the selected hydrograph. To demonstrate, click on Hydrograph 1. The Input Window appears as follows:



SCS Runoff 

Hydrograph No

Name

Runoff Area (ac)

Curve No

Tc Method

Tc (min)

Just fill in the blanks, click **[Compute]** and Hydrology Studio creates your finished hydrograph. Use this procedure for all hydrographs in your basin models. Remember, the Input Window can be accessed from all three tabs, Basin Model, Table and Charts.

To complete this tutorial, enter data for Hydrographs shown in the tables below.

Hydrographs 1 & 2 - SCS Runoff

Item Description	1	2
Name	DA1	DA2
Runoff Area (ac)	2.5	3.0
Curve Number (CN)	80	74
Tc Method	User	User
Tc (min)	20	25

Hydrograph 3 - Junction

Click on Hydrograph number 3, Junction. Enter "Confluence" in the name field and click **[Compute]**.

Hydrograph 4 - Channel Reach

Click on the Reach icon, Hydrograph 4, and enter the following data:

Item Description	4
Name	Int. Channel
Inflow Hydrograph	3
Routing Method	Modified Att-Kin
Section Type	Trapezoidal
Reach Length (ft)	750
Channel Slope (%)	.5
Manning's n	.05
Bottom Width (ft)	5
Side Slope (z:1)	2.5
Maximum Depth (ft)	5
Coeff. x	skip
Coeff. m	skip

Click **[Compute]**

Hydrograph 5 - SCS Runoff

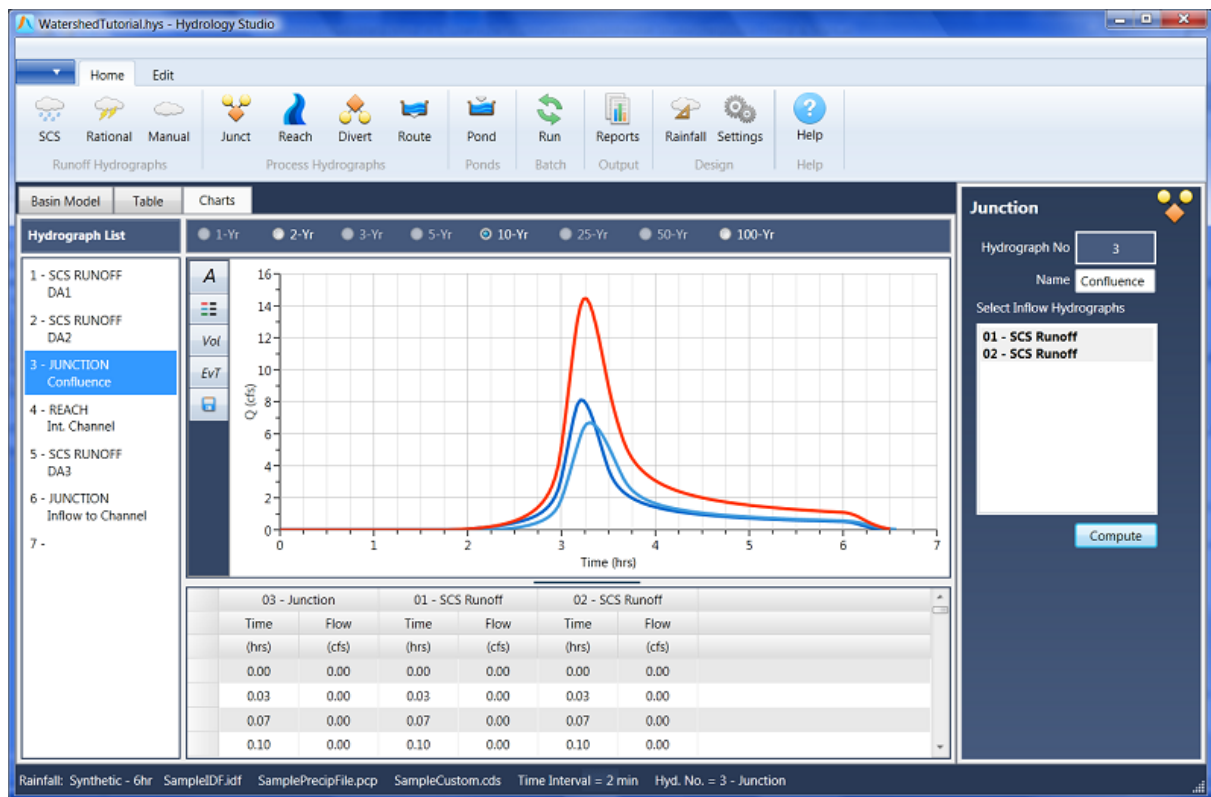
Item Description	5
Name	DA3
Runoff Area (ac)	5.2
Curve Number (CN)	76
Tc Method	User
Tc (min)	30

Click **[Compute]**

Hydrograph 6 - Junction

Click on Hydrograph number 6, Junction. Enter "Inflow to Channel" in the name field and click **[Compute]**.

Now lets take a look at the Charts tab.



Charts Tab showing a plot of Hydrograph 3 "Confluence"

Select any hydrograph to view its corresponding chart. Multiple selections can be made by clicking while holding down the **[Shift]** key. Use the **[Ctrl]** key to select non-adjacent hydrographs.

Note that Hydrology Studio computes hydrographs for all active return periods at once. The frequency selector bar across the top allows you to choose which one to view.

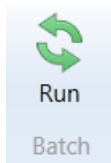
How to Zoom

Any chart in this software can be zoomed by simply dragging a rectangle from the upper left to the lower right of a desired viewport. Double-click the chart to return to full extents.

3.1.1.1 Batch Computing

It's inevitable that once your basin model has been constructed, you'll need to make some changes. For example, the Curve Number for "DA2" in the tutorial might change from 74 to 81. That's easily accomplished by selecting Hydrograph 2 "DA2", editing its CN in the Input Window and clicking **[Compute]**. However, DA2 is an inflow hydrograph and is connected to other downstream hydrographs. So they will need to

be recomputed or updated as well. Batch run offers an easy way to do that.



The Batch Run feature can do this for you in one click rather than recomputing each hydrograph. Another reason to use Batch Run is after making changes to the Precipitation Manager settings. For example, you activated or deactivated additional return periods, changed the Design Storm. Perhaps you selected a new Time Interval in the Settings.

The Auto function begins at Hydrograph No. 1 and works downstream automatically. It simply recomputes each hydrograph, the same as you would do manually, step-by-step. To use this feature, click the **[Run]** button on the Ribbon Toolbar.

3.2 Pre- and Post-development Modeling

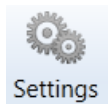
Urban land development drives much of the need for performing pre- and post development analysis and the need for hydrology software. This task typically involves modeling a watershed in both its pre- and post-developed states followed by detention pond design in order to attenuate the post-developed flows to match the pre-developed. Hydrology Studio is well equipped to perform such tasks. It features a wizard-like pond designer that walks you through a 3-step process for creating the detention pond.

Let's start with an example. This time we'll use the Rational Method rather than the SCS method for creating runoff hydrographs.

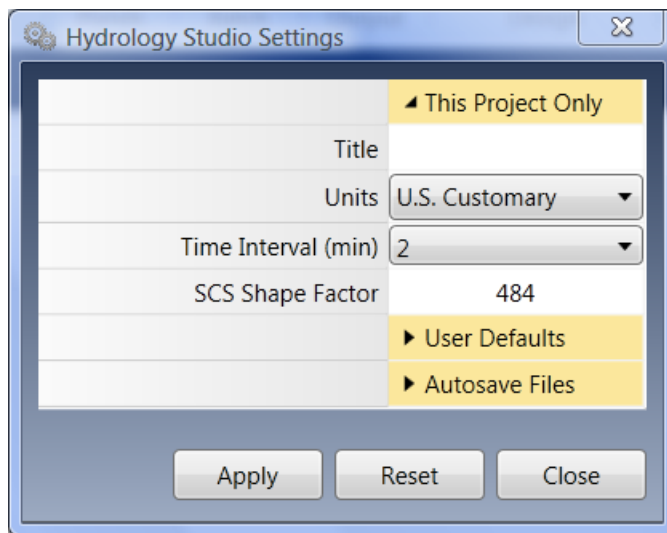
There are just four basic steps:

1. Create the pre-developed hydrograph
2. Create the post-developed hydrograph
3. Design the detention pond to attenuate the post-developed flows to match pre-developed.
4. Route the post-developed hydrograph through the pond.

First, we'll need to be sure the Time Interval is set to one minute. The Time Interval is the increment at which all hydrographs are constructed, e.g., the Q vs. time ordinates are computed at each Time Interval. Since Rational Method hydrographs have short total durations, a small time increment is needed for maximum accuracy.



Start by clicking the **[Settings]** button on the Ribbon Toolbar. This opens the Setting dialog box.



Always use a 1 minute Time Interval for projects that use the Rational method

Click the Time Interval drop-down list box and select 1. Then click **[Apply]**. Then **[Close]**.

[Next we'll create pre- and post-developed hydrographs](#)

3.2.1 Create Pre and Post Hydrographs

Step 1. Create the pre-developed hydrograph

Click the **[Rational]** button on the Ribbon Toolbar. An icon will be placed on the canvas.

Select the icon by clicking it with your mouse. This populates the Input Window as shown below.

Rational Method

Hydrograph No

Name

Runoff Area (ac)

Runoff Coeff (C) %

Tc Method

Tc (min) ...

Calc Method

Ascending Limb x Tc

Receding Limb x Tc

Enter the following information:

Description	Hydrograph 1
Name	<i>Pre-dev</i>
Runoff Area (ac)	4.25
Runoff Coefficient (C)	.68
Tc Method	<i>User</i>
Tc (min)	30
Calc Method	<i>Standard</i>
Ascending Limb	1.0
Receding Limb	1.0

Click **[Compute]**

Step 2. Create the post-developed hydrograph

We can create the post-developed hydrograph by simply repeating Step 1 above.



Note that you cannot add a new Runoff Hydrograph while an existing hydrograph is selected. De-select any hydrographs by clicking anywhere on the canvas.

Click the **[Rational]** button on the Ribbon Toolbar to add a new Rational Method hydrograph.

Click the new icon and enter the following data:

Description	Hydrograph 2
Name	<i>Post-dev</i>
Runoff Area (ac)	4.25
Runoff Coefficient (C)	.84
Tc Method	<i>User</i>
Tc (min)	20
Calc Method	<i>Standard</i>
Ascending Limb	1.0
Receding Limb	1.0

Click **[Compute]**

Your basin model should now look like this:

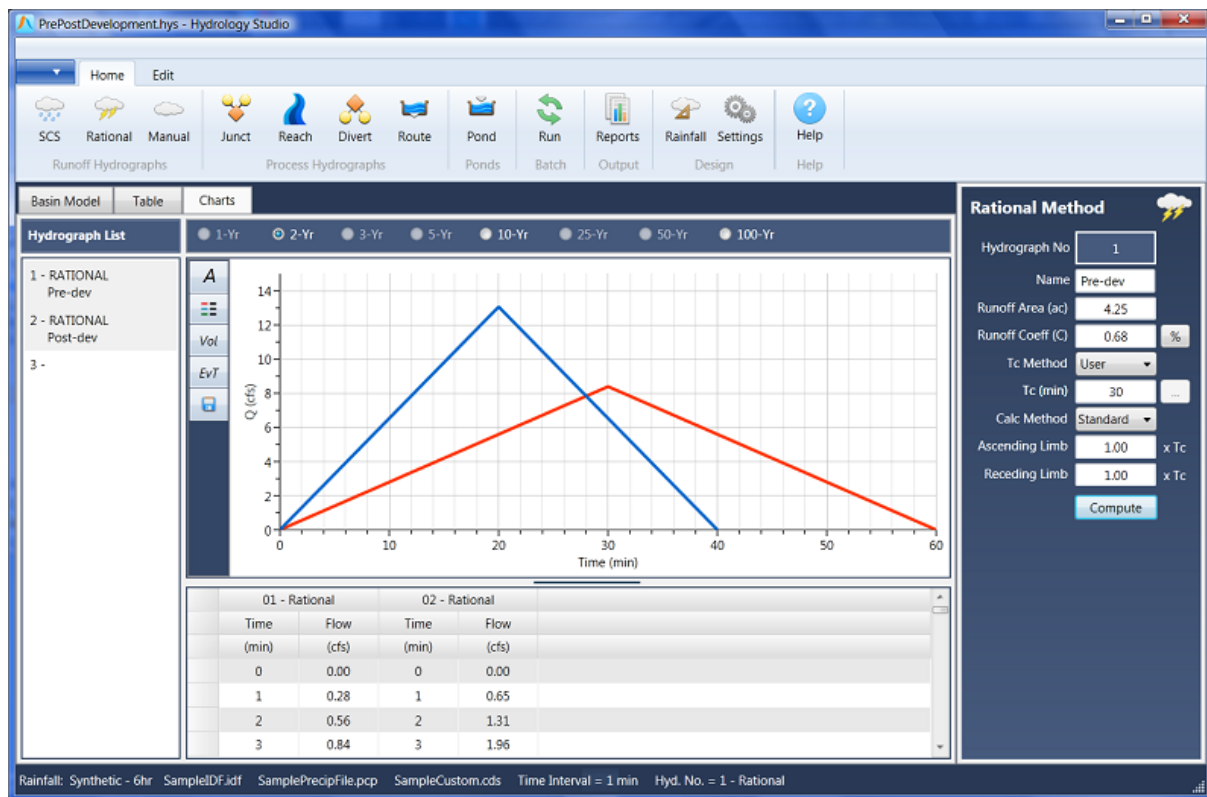
Pre-dev



Post-dev



Take a peak at the results by selecting the Charts or Table tab.



Select both hydrographs to compare pre vs. post

We can view them individually or together by selecting both on the Hydrographs list. The graph above shows the 2-year frequency. Click on the frequency option buttons above to view the 10 and 100-year return periods.

3.2.2 Design Detention Pond

Steps 1 & 2 created the runoff hydrographs for pre- and post-developed conditions. The next step is to create our detention pond. The pre- and post-developed Q_p s are as follows:

Return Period	2	10	100
Pre-developed Q_p (cfs)	8.4	11.44	16.21
Post-developed Q_p (cfs)	13.1	17.41	24.34
Target Q_s (cfs)	8.4	11.44	16.21

The objective is to build a detention pond that will reduce the post-developed flows to that of the pre-developed condition, Target Q_s .

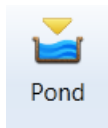
Use the following data which is governed by the physical site conditions:

Outflow culvert length = 25 ft @ 0.50% slope.

We'll use a trapezoidal shaped pond.

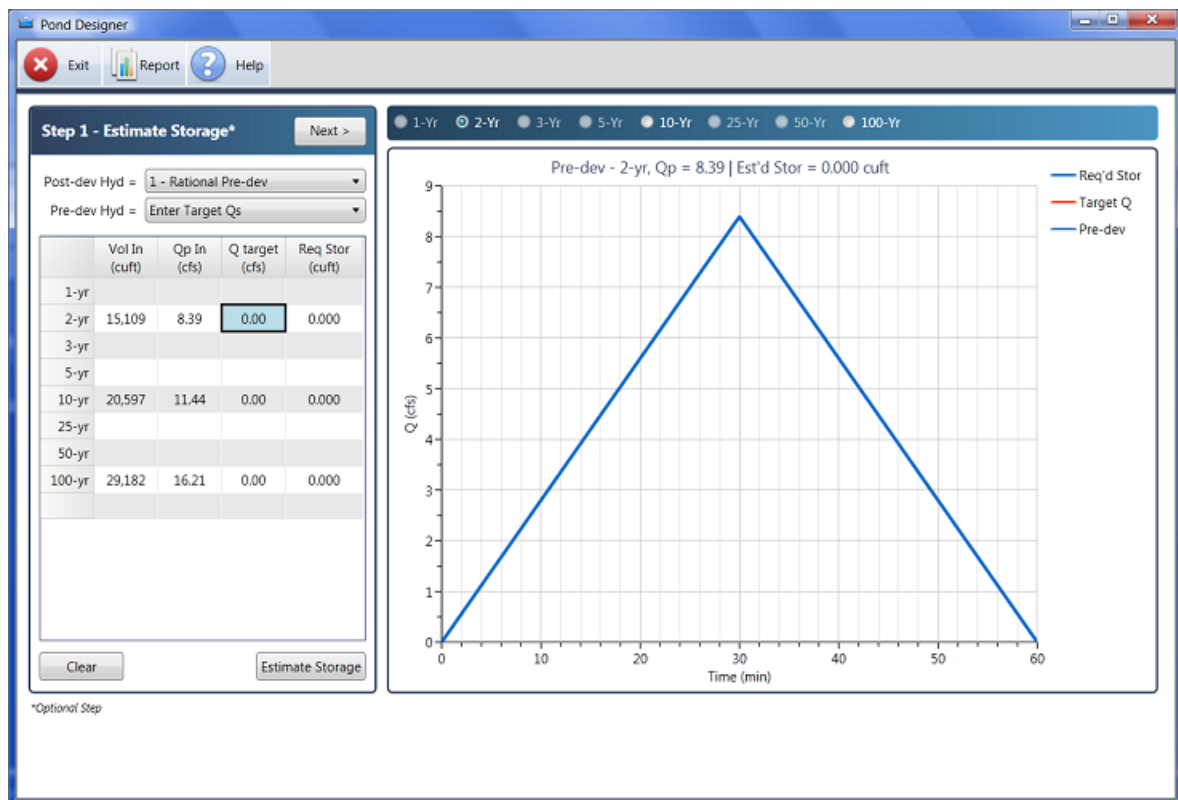
Desired pond side slopes = 2:1.

Allowable pond depth = 6 feet with 1-ft of freeboard; total pond depth = 7 ft.



To begin, click the **[Pond]** button on the Ribbon Toolbar.

This opens the Pond Designer as shown below:



Pond Designer begins with optional Step 1. Estimate Storage

The Pond Designer is wizard-like in that it walks you through 3 steps. You navigate the wizard by clicking on the **[Back]** and **[Next]** buttons on the upper left.

1. [Estimate Storage](#) (optional)
2. [Create Pond](#)
3. [Add Outlets](#)

3.2.2.1 Estimate Storage

This step allows you to estimate the storage required based on your pre- and post-developed hydrographs. It serves as a guide for the following step where you'll build the pond.

Here you'll specify the pre-developed hydrograph by selecting it from the upper drop-down list box.

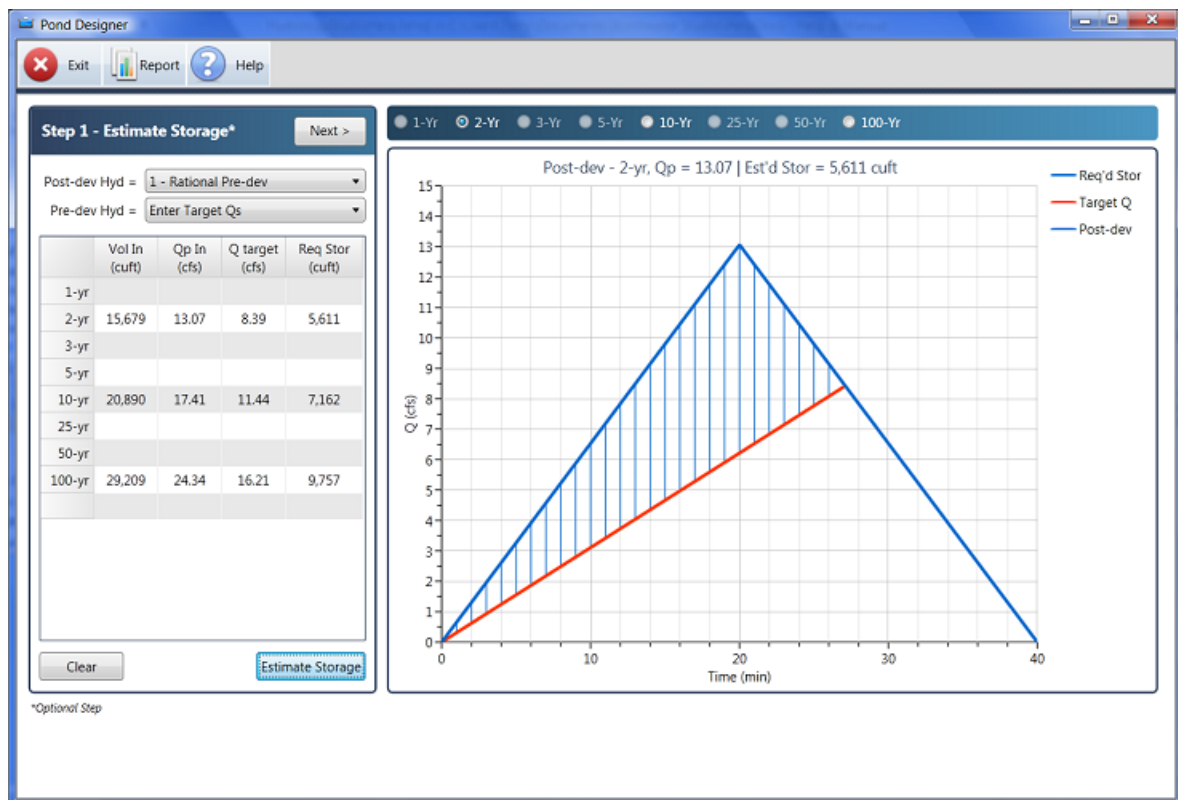
Select Hydrograph 2 as the post and Hydrograph 1 for the pre as shown below.

Post-dev Hyd =

Pre-dev Hyd =

Click **[Estimate Storage]**.

Your screen will similar to this:



Required storage is quickly estimated based on two hydrographs

Keep in mind that this is only an estimate and that the final computed storage post routing may differ somewhat. Hydrology Studio uses a straight-line methodology as shown on the graph. Here it indicates that the total storage needed to attenuate the 100-year peak target Q is approximately 9,757 cuft. This is graphically indicated as the shaded area on the chart.

Proceed by clicking the **[Next]** button which takes you to Step 2 - [Create Pond](#).

3.2.2.2 Create Pond

The following screen appears after clicking **[Next]** from Step 1 - Estimate Storage*:

The screenshot shows the 'Pond Designer' window in Hydrology Studio, specifically the 'Step 2 - Create Pond' tab. The window has a menu bar with 'Exit', 'Report', and 'Help'. Below the menu bar, there are navigation buttons: '< Back', 'Step 2 - Create Pond', and 'Next >'. The main area is divided into two sections. The left section contains input fields for 'Pond No.' (set to '1 - Unused'), 'Pond Name' (empty), and a selection of 'Contours' (highlighted in orange) and 'Manual' (highlighted in blue). Below these are 'Storage Type' (set to 'Contours'), 'Bottom Elevation ft' (set to '0.00'), 'Voids (%)' (set to '100.00'), and 'Volume Calc' (set to 'Conic'). There are 'Clear' and 'Apply' buttons at the bottom of this section. The right section contains a table with the following columns: 'Stage (ft)', 'Elevation (ft)', 'Contour Area (sqft)', 'Incr Stor (cuft)', and 'Total Stor (cuft)'. The table has 21 rows, numbered 0 to 20. Row 0 has values: Stage 0.00, Elevation 0.00, and the other columns are empty. Rows 1 through 20 are empty. There is a 'Done' button at the bottom right of the table.

	Stage (ft)	Elevation (ft)	Contour Area (sqft)	Incr Stor (cuft)	Total Stor (cuft)
0	0.00	0.00			
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					

Hydrology Studio has four options for creating ponds. They can also be combined.

Hydrology Studio has capacity for up to 10 unique ponds. Each pond must be given a name before using. For this pond, enter "PrePost" (no quotation marks) for the pond name.

Next click the **[Trapezoid]** button and fill in the input window with the following:



*You'll see tables like this throughout the program. They function much like an Excel spreadsheet. To edit, double-click on a cell or click once and press **[F2]**.*

Contours	Manual
Trapezoid	UG Chambers

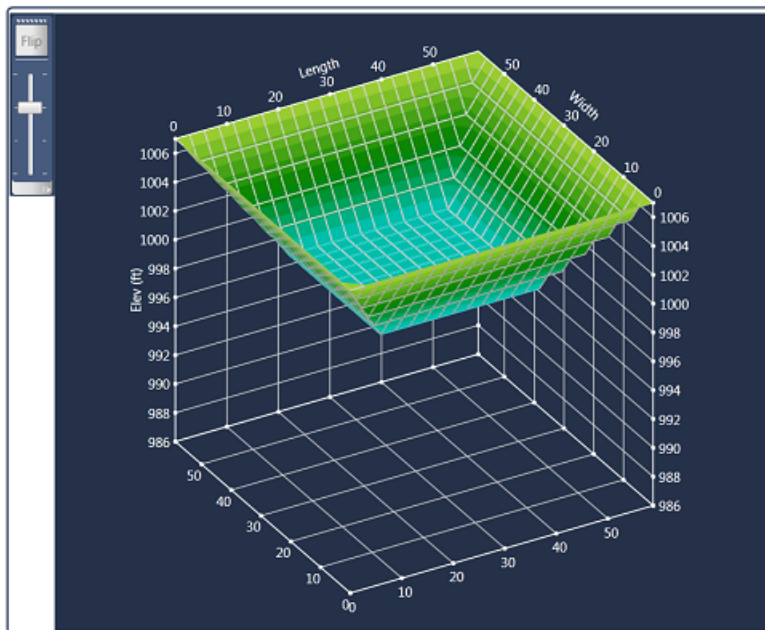
	Input
Storage Type =	Trapezoid
Bottom Elevation ft =	1000.00
Bottom Length ft =	30.00
Bottom Width ft =	30.00
Side Slope, H:1 =	2.00
Total Depth ft =	7.00
Voids (%) =	100.00

The initial size of your pond should always be a little larger than anticipated.

Click **[Apply]** when finished

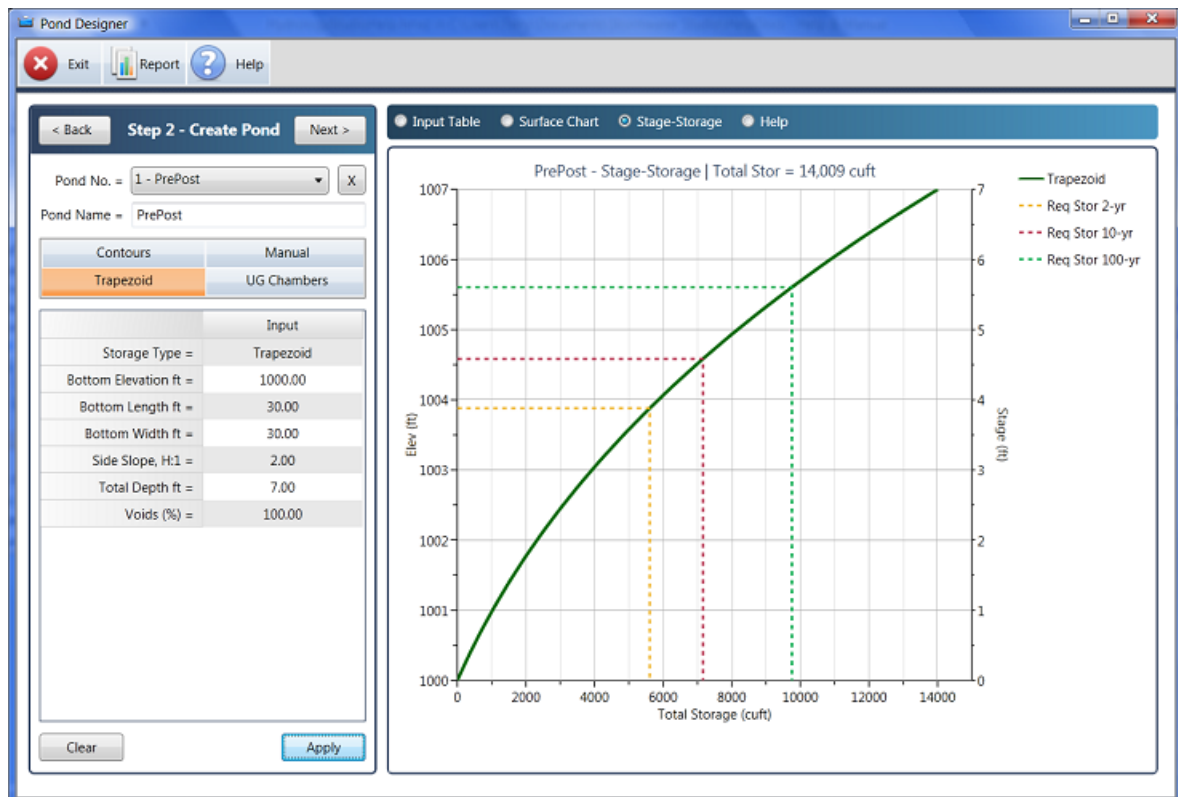
Next, Hydrology Studio populates the adjacent table with the computed results. Note that at the 6-foot stage the pond contains around 11,000 cuft, slightly larger than our target.

Click the **[Surface Chart]** option button on the top of the input table to view the pond in 3D. The slider bar offers differing viewpoints.



A 3-dimensional rendering of your pond

Click the **[Stage Storage]** option button to see a chart.



The dotted lines indicate the required storage and estimated elevations

This completes the Create Pond phase of the tutorial. Now it's time to add outlet structures. Click the **[Next]** button to proceed to Step 3 - [Add Outlets](#).

3.2.2.3 Add Outlets

The following screen appears after clicking **[Next]** from Step 2 - Create Pond:

Pond Designer

Exit Report ? Help

< Back **Step 3 - Add Outlets** Finish

Culvert Riser Orifice Weir
Exfiltration User Perf Riser Tailwater

Input

Outlet Structure = Culvert

Rise (in) = 0.00

Span (in) = 0.00

No. Barrels = 1

Invert Elev. (ft) = 1000.00

Orifice Coeff. (Co) = 0.6

Length (ft) = 0.00

Barrel Slope (%) = 0.00

N-Value (n) = 0.013

Active = ☒

Remove Add/Apply

	Q Target (cfs)	Q Actual (cfs)	Max Elev (ft)	Max Stor (cuft)
2-yr	8.39			
10-yr	11.44			
100-yr	16.21			

Auto Route Trial Route

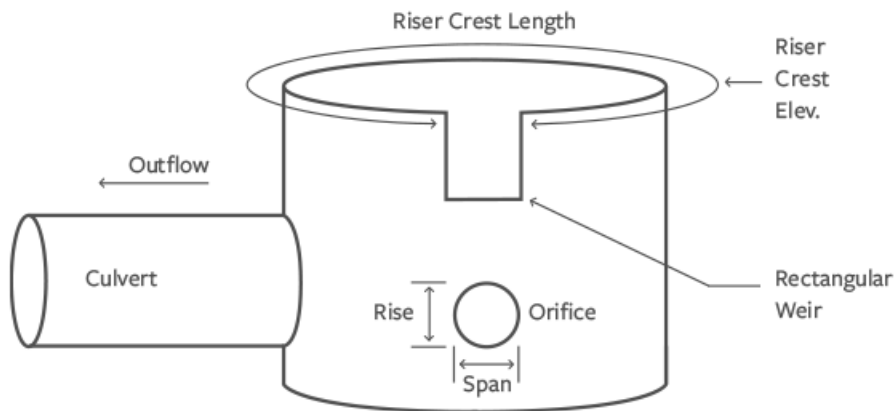
Table Schematic Stage vs. Q Help

Stage (ft)	Elev (ft)	Storage (cuft)	Total Q (cfs)
0.00	1000.00	0.000	0.00
0.04	1000.04	33.0	0.00
0.07	1000.07	66.0	0.00
0.11	1000.11	99.0	0.00
0.14	1000.14	132	0.00
0.18	1000.18	165	0.00
0.21	1000.21	198	0.00
0.25	1000.25	231	0.00
0.28	1000.28	264	0.00
0.32	1000.32	297	0.00
0.35	1000.35	330	0.00
0.39	1000.39	366	0.00
0.42	1000.42	402	0.00
0.46	1000.46	438	0.00
0.49	1000.49	474	0.00
0.53	1000.53	510	0.00
0.56	1000.56	546	0.00
0.60	1000.60	582	0.00
0.63	1000.63	618	0.00
0.67	1000.67	655	0.00

Hydrology Studio offers a wide variety of outlet structures and configurations

A multi-stage structure like the one below will be used for this demonstration since we are targeting multiple return periods.

Riser Structure*



*Shown in multi-stage configuration.

Start by clicking the **[Culvert]** button and then fill in table as follows:

Culvert	Riser	Orifice ▼	Weir ▼
Exfiltration	User	Perf Riser	Tailwater

	Input
Outlet Structure =	Culvert
Rise (in) =	18.00
Span (in) =	18.00
No. Barrels =	1
Invert Elev. (ft) =	1000.00
Orifice Coeff. (Co) =	0.6
Length (ft) =	25.00
Barrel Slope (%) =	0.50
N-Value (n) =	0.013
Active =	☒

Remove
Add/Apply

Click [Add/Apply] when done.

Click **[Riser]** and add the following inputs:

Culvert	Riser	Orifice ▾	Weir ▾
Exfiltration	User	Perf Riser	Tailwater

	Input
Outlet Structure =	Riser
Riser Shape =	Box ▾
Crest Elevation (ft) =	1006.00
Crest Length (ft) =	16.00
Weir Coeff. (Cw) =	3.33
Multi-Stage =	☒
Active =	☒

Remove Add/Apply

Click [Add/Apply] when done. Multi-stage indicates it flows through the Culvert.

Click **[Orifice]** and select Orifice 1. Add the following inputs:

	Input
Outlet Structure =	Orifice 1
Rise (in) =	15.00
Span (in) =	15.00
No. Barrels =	1
Invert Elev. (ft) =	1000.01
Orifice Coeff. (Co) =	0.6
Multi-Stage =	☒
Active =	☒

Click [Add/Apply] when done.

Click **[Weir]** and select Weir 1. Add the following inputs:

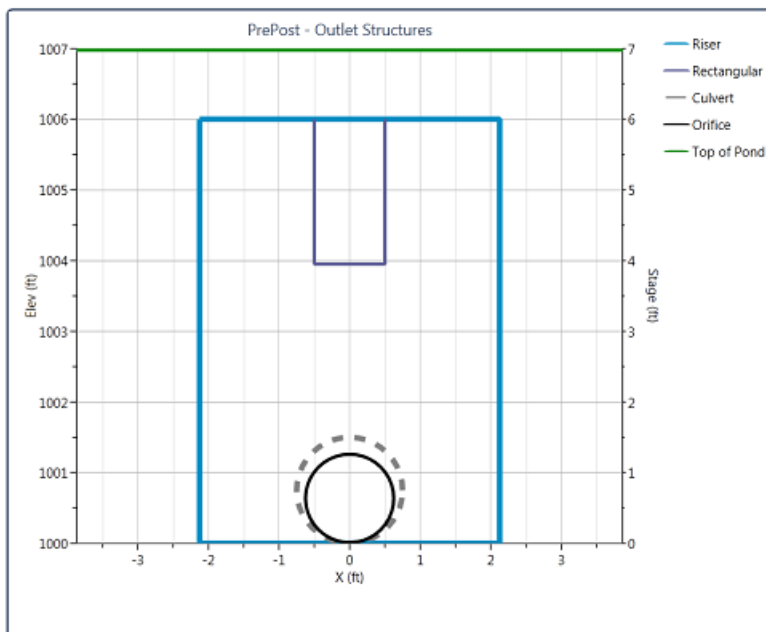
	Input
Outlet Structure =	Weir 1
Weir Type =	Rectangular ▼
Crest Elevation (ft) =	1003.95
Crest Length (ft) =	1.00
Weir Coeff. (Cw) =	3.33
Multi-Stage =	☒
Active =	☒

Click [Add/Apply] when done.

This completes the required input for our outlet structures. You may have noticed the Stage-Storage-Discharge Table populate while adding devices. Click on the **[Schematic]** option button to view a front sectional drawing of your multi-stage structure.

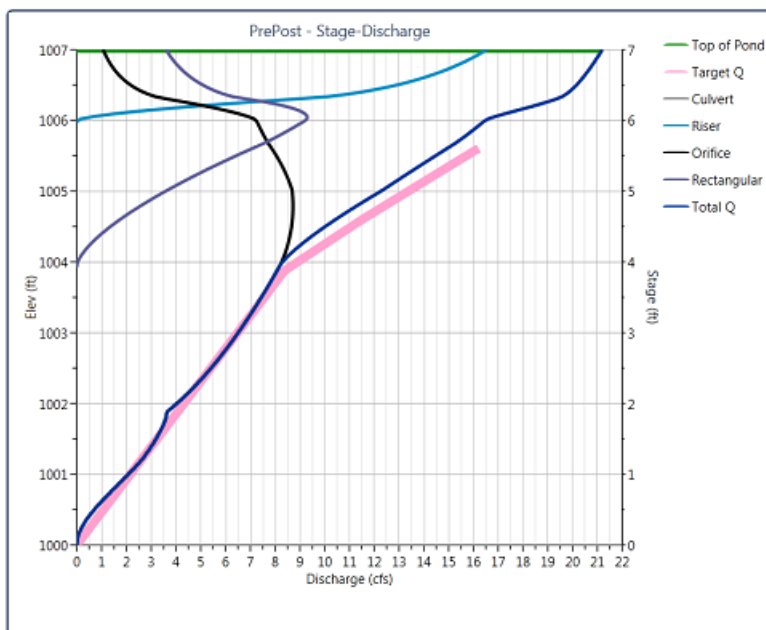


*When viewing the Schematic for the first time circular devices may appear elliptical. Click **[Add/Apply]** in order to render with the correct aspect ratio.*



Multi-stage structure with Culvert, Riser, Orifice & Weir.

Next, click the **[Stage vs Q]** option button. The following screen appears:



This innovative chart reduces the guesswork of sizing outlets

This chart shows Stage vs. Q for each device as well as the actual Total Q. The large pink line is our target. When designing ponds, your objective is to add outlet structures

so that your Total Q line approximately matches the Target Q line as it does above.

Trial Route

When *Step 1 - Estimate Storage* has been completed as was in this tutorial, Hydrology Studio provides a way to perform a trial route to see the outcome of your routing immediately while editing outlet structures. A much faster way to achieve a final design.

Click **[Trial Route]**. The table below gives the result and as one can confirm, the Actual Qs are at or below their Target Qs.

	Q Target (cfs)	Q Actual (cfs)	Max Elev (ft)	Max Stor (cuft)
2-yr	8.39	8.11	1003.90	5,656
10-yr	11.44	11.36	1004.81	7,697
100-yr	16.21	16.19	1005.92	10,640

☐ Auto Route

Trial Route



The sizes and placement of the outlet structures were previously designed to meet the target outflows. It was a simple process that took just a few minutes. Be sure to read the sections regarding detention ponds later in this guide for tips and best practices.

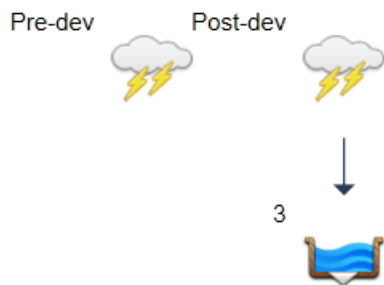
We are now ready to complete the basin model. Click the **[Finish]** or **[Exit]** button and proceed to:

Step 4. [Route](#) the post-developed hydrograph through the pond.

3.2.3 Perform Pond Routing

Now that our pond is built all we need to do to finish is route Hydrograph 2 "PostDev" through it.

Select the "PostDev" hydrograph and then click the **[Route]** button on the Ribbon Toolbar. Your basin model diagram should look like the following:



*Icons for actual ponds are not used
on the Basin Model*

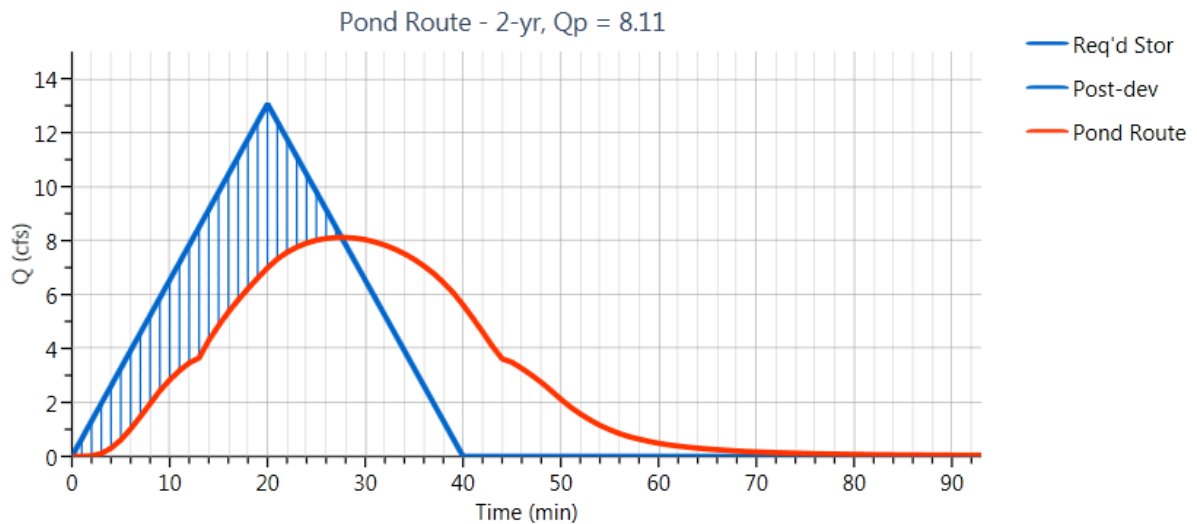
Double-click Hydrograph 3 and fill in the Input Table as follows:

The 'Pond Route' dialog box is shown with the following settings:

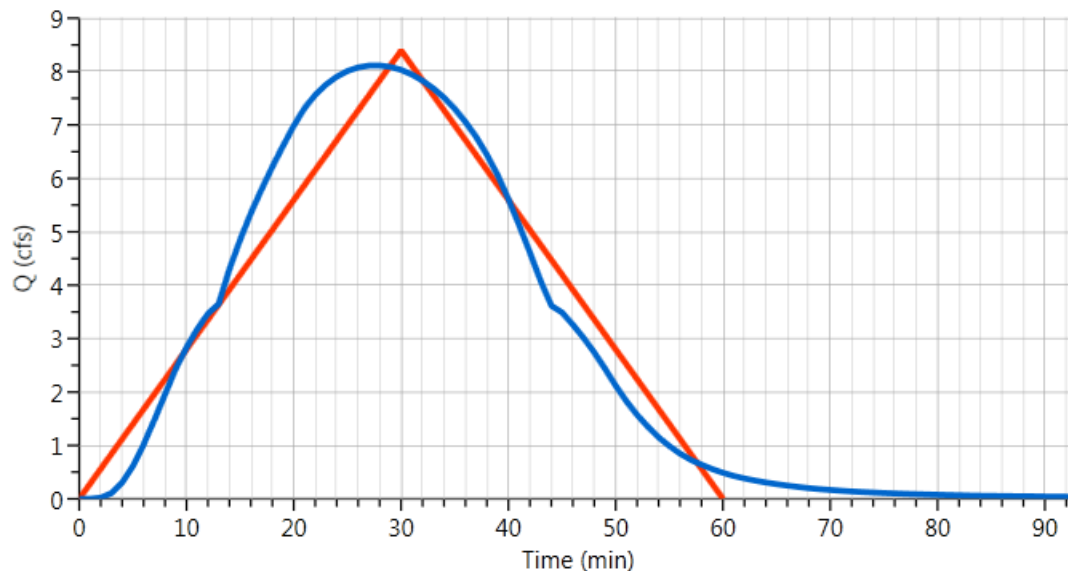
- Hydrograph No: 3
- Name: Pond Route
- Inflow Hyd: 2 - Rational
- Pond Name: 1 - PrePo: ...
- Lower Pond: ☐ 1 - PrePo: ...
- Wet Pond Elev: Dry pond
- Compute button

Click **[Compute]** when done.

Select the Charts tab to see the resulting graph.



Select Hydrographs 1 & 3 (hold the Ctrl key while clicking) to see how the pond-routed hydrograph matches the pre-developed hydrograph.

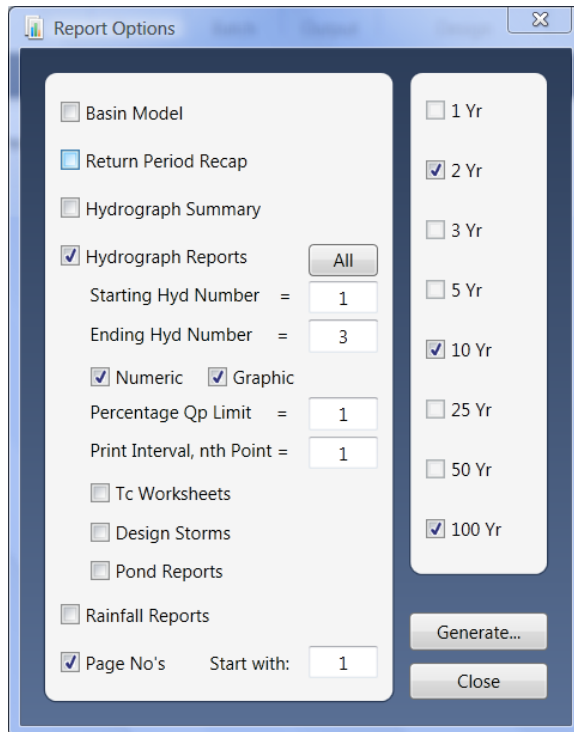


This concludes the tutorial on creating a pre- and post-development model. Please check www.hydrologystudio.com support pages for related videos.

3.3 Getting Output

Getting printed reports in Hydrology Studio is quite easy. Reports are available at any time and there's no rigid procedure to follow or preparation work. Just click the

[Reports] button, typically located on the Ribbon Toolbar, and Hydrology Studio displays its Reports Menu. It has an automatic print preview.



The print menu offers many report options

Just pick & choose the types of reports you want and click **[Generate]**. That opens up the Document Viewer where you'll see a preview of your reports. From there you can send them to your printer for hard copies.

Report Options

If you're not sure what report types you like, feel free to explore by checking those items and reviewing them on the print preview. Although most options are self explanatory, below are some descriptions for clarity.

Starting & Ending Hydrograph Numbers - Use this to select a range of hydrographs to be printed. Enter the beginning and ending hydrograph numbers. Click the **[All]** button to quickly select all hydrographs within the basin model.

Numeric and Graphic - You can choose to have the reports contain a graphical and/or numerical output.

Percentage Qp Limit - This is useful for saving paper or just limiting the volume of numerical-based output. The reports will only include those Q's that are above this minimum setting. For example, a Qp Limit of 20 will limit the Q vs Time table to flow

rates greater than $0.20 \times Q_p$. Note this only applies to the numerical output, not graphical.

Print Interval, nth Point - This feature allows you to limit the numerical output by selecting to print every nth point on the hydrograph. For example, you may wish to print only every 4th ordinate on the hydrograph to save paper. If so, enter 4 for this item. Note however that printing at larger intervals can cause the report to miss the peak flow ordinate.

Frequencies - The panel on the right allows you to choose with return periods to include. The inactive ones are disabled.

3.3.1 Exporting

Charts

You can export any Hydrology Studio chart (except the 3D Surface) to a file. The following file formats are supported:

*.jpeg, *.bmp & *.png.

To export a chart, right-click and select "Save this chart" on the pop-up context menu. A Save dialog box will assist you.

Grids

Most output grids can also be exported. Supported file formats include:

*.Csv, *.txt & *.html

To export a grid, right-click and select "Export this grid" on the pop-up context menu. A Save dialog box will assist you.

Part

IV

4 Basic Working Procedures

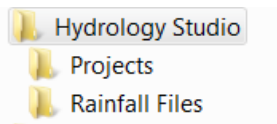
This section describes the most common basic tasks you will use when working with Hydrology Studio. It is designed as a "How-To" guide and reference manual. Although it is organized roughly in the order that you would perform the tasks you want, you don't need to start at the beginning and work your way through. Every topic contains comprehensive links to background information and other relevant subjects so you can just pick out the task you need to perform and begin.

As explained in the [Overview](#) section, this hydrology software has a very simple Main Window where you'll perform most tasks. Hopefully you've become acquainted with this main window during the [Quick Start Tutorials](#) so it won't be discussed in more detail here.

What should you do first? If you have read the Overview and Quick Start Tutorials, then there are two things you should do.

1. Create a folder on your computer to hold your project files

Hydrology Studio uses Microsoft's "Click-Once" technology to install itself on your computer. As you may have noticed, it was very fast and easy. While it's void of confusing options, it does not create file folders for your projects. It is recommended you create a folder to hold these. For example the following folder configuration is recommended under your Documents folder:



The Projects folder will contain your project files (*filename.hys*) while the Rainfall Files will contain your rainfall data described in the following section.

2. Set up your local rainfall files - The hydrology software ships with default rainfall data for which is useful while getting to know the program. But eventually you'll want to setup your own local data.

Tip: The companion product, "Stormwater Studio" uses the same IDF file. If you are already using this product, you may open the rainfall files from its folder and use for this software as well.

4.1 Setting Up Rainfall

During calculations Hydrology Studio automatically uses it's built-in rainfall data. The software ships with default data for which is useful while getting to know the program. But eventually you'll want to setup your own local data. There are three different files

it uses:

1. **IDF Curves** - For use in computing flows for the Rational Method and developing Synthetic Design Storms
2. **Precipitation Data** - For automatic multiple return period processing and rainfall totals for use in SCS-based hydrographs
3. **Custom Design Storms** - While Hydrology Studio has an entire library of built-in storms, this file holds custom storms as well.

Hydrology Studio automatically manages these files for you in that it opens them upon launch and saves them when exiting if anything has changed. These three files should be saved in your Hydrology Studio/Rainfall Files folder. You may also choose to store them in any other folder you wish. The files currently in use is shown in the Status Bar at the bottom of the Main Window.



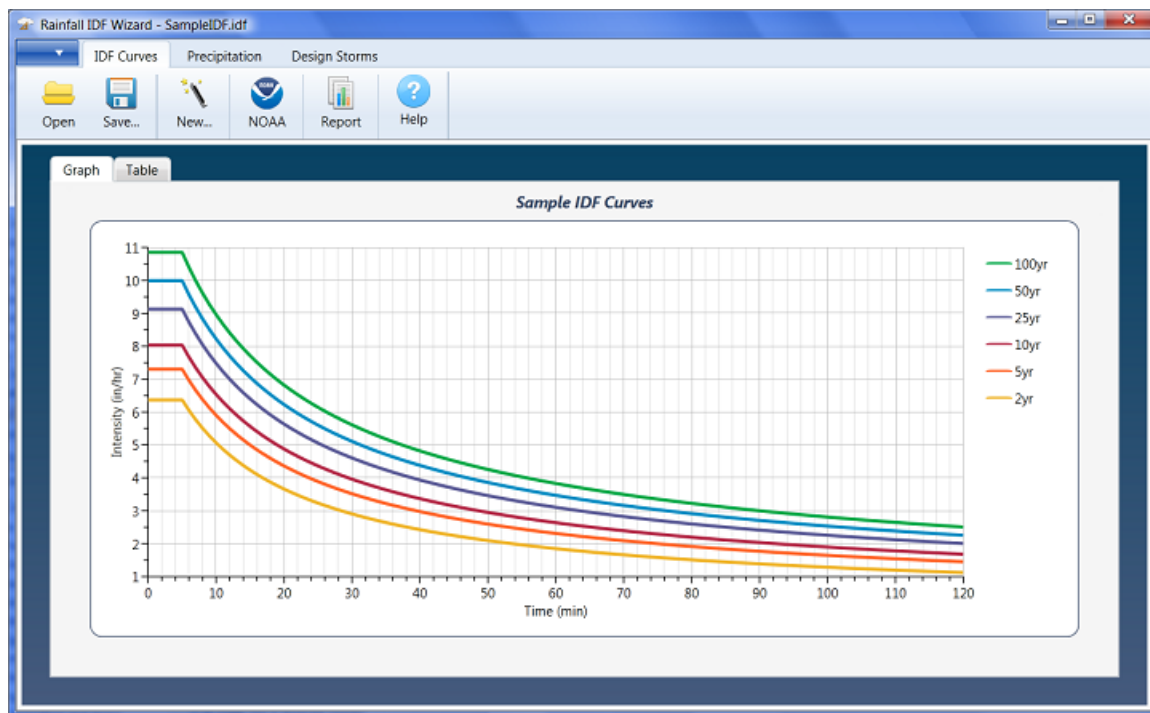
All rainfall files are embedded in each project file so it is not necessary, for example, to email an associate, the .hys project file and the associated rainfall files.

4.1.1 IDF Curves

Hydrology Studio allows you to customize the IDF rainfall data. It provides a variety of methods to choose from for setting them up.



To begin, click the **[Rainfall]** button on the Ribbon Toolbar to open the Rainfall IDF Wizard.



Hydrology Studio offers a Wizard to setup your IDF Curves. Click New to begin.

This screen displays the current set of IDF curves. Note that IDF curves, no matter what method was used to develop, are equation-based in the end and have no time limit even though the graph displayed only shows intensities up to 120 minutes. Click the Table tab to view the curves in numeric format. The curves cannot be edited on this screen.



To create a new set of curves, click the **[New]** button. This opens the IDF Wizard which will walk you through a series of steps.

IDF Wizard walks you through the steps

You have three choices to start.

1. [Create using rainfall map data](#) - Use this method to enter precipitation values directly from Hydro-35 (Eastern United States) or NOAA Atlas 2 Maps (Western United States). Use this method if your state is NOT listed on NOAA Atlas 14.
2. [Enter intensities directly](#) from your existing IDF curves or import from the newest NOAA Atlas 14.
3. [Enter known equation coefficients](#). Hydrology Studio uses two types of equations, FHA (IDF Equation) and Third-degree Polynomial. You may directly enter coefficients for these rainfall intensity equations.

4.1.1.1 Using Rainfall Map Data

Hydrology Studio has the ability to generate IDF curves from NWS precipitation data. The computational procedure is that as described in FHA Circular No. 12, "Drainage of Highway Pavements."

Technically, when using Hydro-35 data or existing curves, Hydrology Studio manipulates your input data to generate coefficients B, D & E, for use in an Intensity vs. Tc equation shown below.

$$I = \frac{B}{(Tc + D)^E}$$

This method requires minimal inputs but varies depending on what part of the U.S. you are defining and if NOAA has updated data available for your state.



*Your best source for this data is from NOAA's National Weather Service "Precipitation Frequency Data Server". Click the **[NOAA]** button on the Ribbon Toolbar to open the web server. Then select your state and follow the instructions. Set the Data type to "Precipitation Depth, Partial Duration" when using it for IDF curve setup.*

DATA DESCRIPTION

Data type: Units: Time series type:

If you are in the Eastern Contiguous United States

The IDF Wizard will display this screen:

Hydrology Studio IDF Curves Wizard
Enter Rainfall Amounts from Hydro-35 Maps

	5-min	15-min	60-min
2-year (in)	.53	1.07	1.85
100-year (in)	.9	1.82	3.83

Note: Enter rainfall amounts in whole in.

Sample data shown

Enter the 5-, 15- and 60-minute precipitation amounts for the 2- and 100-year return periods and click **[Finish]**. You'll be taken back to the initial IDF Wizard screen where you'll see your new IDF curves. See also [IDF Correction Factors](#).

Save your curves by clicking the **[Save]** button and specifying a name for your file. An ".idf" extension will be applied. This file will automatically open each time you launch Hydrology Studio. You can, of course, change this file any time afterwards.

If you are in the Western United States

The IDF Wizard will display this screen:

Hydrology Studio IDF Curves Wizard
Enter Rainfall Amounts from NOAA Atlas 2 Maps

	6-hour	24-hour
2-year (in)	0	0
100-year (in)	0	0
State-Region	Please choose... ▼	
Ave. elevation (ft)	0	

Note: Enter rainfall amounts in whole in.

Enter the 6- and 24-hour precipitation amounts for the 2- and 100-year return periods. Select your state from the dropdown list. Note that only some states require an elevation input.

Click **[Finish]** to generate the curves. You'll be taken back to the initial IDF Wizard screen where you'll see your new IDF curves. See also [IDF Correction Factors](#).

Save your curves by clicking the **[Save]** button and specifying a name for your file. An ".idf" extension will be applied. This file will automatically open each time you launch Hydrology Studio. You can, of course, change this file any time afterwards.

Click the **[Open]** or **[Save]** buttons to open or save an existing idf file.

4.1.1.2 Enter Points from Existing Curves

Hydrology Studio allows you to enter intensities directly from your existing IDF curves. You can also enter or import intensities from the newest NOAA Atlas 14.



*Your best source for this data is from NOAA's National Weather Service "Precipitation Frequency Data Server". Click the **[NOAA]** button on the Ribbon Toolbar to open the web server. Then select your state and follow the instructions. Set the Data type to "Precipitation Intensity, Partial Duration" when using it for IDF curve setup.*

DATA DESCRIPTION

Data type: Units: Time series type:

If you selected "Enter Intensities from Existing IDF Curves or NOAA Atlas 14" the following screen appears:

Hydrology Studio IDF Curves Wizard
 Enter Intensities from Existing IDF Curves or NOAA Atlas 14

	1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr
5-min	0	6.37	0	7.30	8.03	9.13	9.99	10.85
15-min	0	4.24	0	5.00	5.56	6.40	7.06	7.71
30-min	0	2.90	0	3.52	3.96	4.60	5.11	5.61
60-min	0	1.85	0	2.31	2.64	3.10	3.47	3.83

Note: Enter rainfall intensities in in/hr.

Clear Import... Apply

Back Next Finish Cancel

Enter intensities directly or import from NOAA

Clear the table and enter intensities directly into the table. Click **[Apply]**.

Then click **[Finish]**. You'll be taken back to the initial IDF Wizard screen where you'll see your new IDF curves. See also [IDF Correction Factors](#).

Save your curves by clicking the **[Save]** button and specifying a name for your file. An ".idf" extension will be applied. This file will automatically open each time you launch Hydrology Studio. You can, of course, change this file any time afterwards.

How to Import from NOAA Atlas 14

Provided your state is one which is listed on this atlas, you can quickly import this data by first exporting it from NOAA's Precipitation Frequency Data Server. To start, click the **[NOAA]** button on the Ribbon Toolbar to open the web server. Then select your state and follow the instructions. Be sure to set the Data type to "Precipitation Intensity, Partial Duration" as shown above.

At the bottom of the PF Tabular table you'll see an option to export as a .csv file.

 Estimates from the table in csv format:

Click **[Submit]**. The file will open in your web browser, or other text viewer, and will look similar to the following:

```
Point precipitation frequency estimates (inches/hour)
NOAA Atlas 14, Volume 2, Version 3
Data type: Precipitation intensity
Time series type: Partial duration
Project area: Ohio River Basin
Latitude (decimal degrees): 33.8000
Longitude (decimal degrees): -81.0000
```

PRECIPITATION FREQUENCY ESTIMATES

```

by duration for ARI:, 1,2,5,10,25,50,100,200,500,1000 years
5-min:, 5.51,6.37,7.26,8.17,9.19,10.04,10.86,11.65,12.62,13.51
10-min:, 4.40,5.09,5.81,6.54,7.32,8.00,8.63,9.23,9.98,10.64
15-min:, 3.66,4.27,4.90,5.52,6.18,6.76,7.27,7.77,8.38,8.90
30-min:, 2.51,2.95,3.48,4.00,4.58,5.09,5.57,6.05,6.66,7.21
60-min:, 1.57,1.85,2.23,2.60,3.05,3.45,3.83,4.24,4.78,5.26
2-hr:, 0.90,1.07,1.30,1.54,1.83,2.10,2.37,2.67,3.06,3.43
3-hr:, 0.63,0.75,0.92,1.10,1.32,1.53,1.75,1.98,2.32,2.63
6-hr:, 0.38,0.45,0.55,0.65,0.79,0.91,1.05,1.19,1.40,1.60
12-hr:, 0.22,0.26,0.32,0.38,0.46,0.54,0.62,0.72,0.85,0.97
24-hr:, 0.12,0.15,0.19,0.22,0.27,0.32,0.36,0.42,0.50,0.57
2-day:, 0.07,0.09,0.11,0.13,0.16,0.18,0.21,0.24,0.28,0.32
3-day:, 0.05,0.06,0.08,0.09,0.11,0.13,0.14,0.16,0.19,0.22
4-day:, 0.04,0.05,0.06,0.07,0.09,0.10,0.11,0.13,0.15,0.17
7-day:, 0.03,0.03,0.04,0.05,0.06,0.06,0.07,0.08,0.09,0.10
10-day:, 0.02,0.03,0.03,0.04,0.04,0.05,0.05,0.06,0.07,0.08
20-day:, 0.01,0.02,0.02,0.02,0.03,0.03,0.03,0.04,0.04,0.04
30-day:, 0.01,0.01,0.02,0.02,0.02,0.02,0.03,0.03,0.03,0.03
45-day:, 0.01,0.01,0.01,0.02,0.02,0.02,0.02,0.02,0.02,0.02
60-day:, 0.01,0.01,0.01,0.01,0.01,0.02,0.02,0.02,0.02,0.02

```

Date/time (GMT): Tue Nov 20 20:02:01 2012

pyRunTime: 0.0222988128662

Save this file as a .txt or .csv file, preferably in your Hydrology Studio/Rainfall folder.

Next, click the **[Import]** button on the Hydrology Studio IDF Wizard screen shown above. Select the file you just saved and click **[Open]**.

Click **[Apply]**.

Then click **[Finish]**. You'll be taken back to the initial IDF Wizard screen where you'll see your new IDF curves.

Save your curves by clicking the **[Save]** button and specifying a name for your file. An ".idf" extension will be applied. This file will automatically open each time you launch Hydrology Studio. You can, of course, change this file any time afterwards.

4.1.1.3 Known Equation Coefficients

Even though there are several ways to setup your IDF Curves in the beginning, once completed, they take the form of an equation. Hydrology Studio uses two types of equations. Each can accept custom coefficients to match your exact IDF curves.

To enter your own coefficients, select Enter Known Equation Coefficients from the IDF Wizard opening screen. Choose one of the following equation types:

IDF Curve Equation

This method takes on the form:

$$I = \frac{B}{(Tc + D)^E}$$

Where:

I = rainfall intensity
Tc = time in minutes
B = coefficient
D = coefficient
E = coefficient

Third Degree Polynomial Equation

Some regions have IDF curves which are based on a third-degree polynomial equation. These curves typically do not plot as a straight line on log-log scales. You have the option of creating IDF curves using a third degree polynomial equation as follows:

$$I = A + BX + CX^2 + DX^3$$

Where:

I = rainfall intensity
X = Ln(time in minutes)
A = coefficient
B = coefficient
C = coefficient
D = coefficient

A screen similar to the following appears:

Hydrology Studio IDF Curves Wizard
Enter Known Equation Coefficients, $I = B/(T_c + D)^E$

	1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr
Cf	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
B	0.0000	58.1215	0.0000	57.1446	58.8780	63.5498	67.7965	72.2003
D	0.0000	10.3000	0.0000	10.3000	10.3000	10.4000	10.5000	10.6000
E	0.0000	0.8106	0.0000	0.7542	0.7303	0.7097	0.6986	0.6898
	-	-	-	-	-	-	-	-

Note: Cf = Frequency Correction Factor applied to Runoff Coefficients, C.

Clear Apply

Back Next Finish Cancel

Specify your own equation coefficients.

Clear the table if needed and enter B, D & E coefficients. If using Third Degree Polynomial, enter the A, B, C, & D coefficients. Note you can also specify Frequency Correction Factors, Cf on this screen. For more information, see [IDF Correction Factors](#).

When finished, click the **[Apply]** button and then **[Finish]**. You'll be taken back to the initial IDF Wizard screen where you'll see your new IDF curves. See also [IDF Correction Factors](#).

Save your curves by clicking the **[Save]** button and specifying a name for your file. An ".idf" extension will be applied. This file will automatically open each time you launch Hydrology Studio. You can, of course, change this file any time afterwards.

4.1.1.4 IDF Correction Factors

You can enter Frequency Correction Factors, Cf, with your IDF Curves. The Cf factors can be edited on the Known Equation Coefficients screen or the Computed Coefficients screens.

Cf factors are applied to the Runoff coefficients when computing peak flows for the Rational Method. They do not affect Synthetic Design Storms.

Correction Factors can be edited while you are setting up your IDF curves. Rather than clicking **[Finish]** just after entering or importing data, continue to click **[Next]** until you arrive at the Equation Coefficients screen. There you can enter Cf values. Remember to click the **[Apply]** button.

Hydrology Studio IDF Curves Wizard
Enter Known Equation Coefficients, $I = B/(Tc + D)^E$

	1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr
Cf	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
B	0.0000	58.1215	0.0000	57.1446	58.8780	63.5498	67.7965	72.2003
D	0.0000	10.3000	0.0000	10.3000	10.3000	10.4000	10.5000	10.6000
E	0.0000	0.8106	0.0000	0.7542	0.7303	0.7097	0.6986	0.6898

Note: Cf = Frequency Correction Factor applied to Runoff Coefficients, C.

Clear Apply

Back Next Finish Cancel

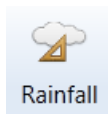
Edit the frequency correction factors, Cf, as needed.

4.1.2 Precipitation & Events

Hydrology Studio offers automatic multiple return period processing. In other words, it computes your model for any and all return periods at the same time. There's no need to rerun your model for each event.

You simply activate the return periods you need to use. Each hydrograph you create will then be calculated for each activated frequency using the corresponding precipitation values entered at this screen. Like the IDF curves, you can save the values as an event file for loading at a later time. Similarly, these files are automatically saved when you exit the program and reloaded upon its start. These files become part of all project files. Thus it is not necessary, for example, to email an associate, the .hys project file and the associated event file. As the IDF file, it's already embedded in the .hys project file.

Hydrology Studio has a full library of built-in design storms from which you can pick and choose at any time. Their names are listed on the Precipitation Manager screen. Their full detailed hyetographs can be viewed from the "[Design Storms](#)" tab.



To begin, click the **[Rainfall]** button on the Main Window Ribbon Toolbar to open the Rainfall IDF Wizard. Select the "Precipitation" tab on the Ribbon Toolbar. The Precipitation Manager screen should look like the following:

Hydrology Studio Precipitation Manager
 Activate Project Design Storms. Enter Precipitation.

	Active	1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr
Active	☐	☒	☐	☐	☐	☒	☐	☐	☒
SCS Storms	▶ SCS Dimensionless Storms								
IDF-Based	▶ IDF-Based Synthetic Storms (Synthetic - 6hr is Active)								
Huff Distribution	▶ 1st Quartile (0 to 6hrs)								
Huff Distribution	▶ 2nd Quartile (>6 to 12 hrs)								
Huff Distribution	▶ 3rd Quartile (>12 to 24 hrs)								
Custom Storms	▶ Custom Storm Distributions								

Note: Enter precipitation values in whole inches.

Clear Import... Apply

Enter precipitation amounts and activate return periods on this screen

This screen basically needs three things:

1. Which return periods you want your project(s) to use;
2. Which storm distribution you want to use;
3. Rainfall precipitation amounts associated with Items 1 & 2.

Activate Return Periods

The top row of the table lists the available frequencies. Just below that are check boxes used to activate those frequencies. Simply check those you wish to use. The screen above indicates the 2, 10 and 100 year events are active.

Activate Design Storm Distribution

Click on the row header arrow corresponding to the desired design storm. This drops-down the list of available durations. For example, clicking on SCS Dimensionless Storms displays the following:

Hydrology Studio Precipitation Manager
 Activate Project Design Storms. Enter Precipitation.

	Active	1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr
Active	☐	☒	☐	☐	☐	☒	☐	☐	☒
SCS Storms	▶ SCS Dimensionless Storms								
Std. 6-hr	☐	1.20	1.50	0	1.86	2.18	2.64	3.01	3.41
Type I	☐	1.82	2.28	0	2.85	3.31	3.94	4.43	4.94
Type IA	☐	1.82	2.28	0	2.85	3.31	3.94	4.43	4.94
Type II	☐	1.82	2.28	0	2.85	3.31	3.94	4.43	4.94
Type II FL Mod	☐	1.82	2.28	0	2.85	3.31	3.94	4.43	4.94
Type III	☐	1.82	2.28	0	2.85	3.31	3.94	4.43	4.94
IDF-Based	▶ IDF-Based Synthetic Storms (Synthetic - 6hr is Active)								

Note: Enter precipitation values in whole inches.

Clear Import... Apply

Click on the row header arrow to view the available design storms

To activate a distribution, simply click its corresponding check-box under the "Active" column. Please see [Custom Design Storms](#) to learn how to create your own distribution. Storms can also be activated from the [Design Storms](#) tab.



Only one storm can be active at a time.

Enter Rainfall Precipitation Amounts

The last step in setting up your Precipitation & Events is specifying the rainfall amounts local to your area. There are two ways to accomplish this:

1. Enter the rainfall amounts manually;
2. [Import from NOAA's National Weather Service "Precipitation Frequency Data Server"](#)

To enter manually, simply type in the rainfall amounts associated with the selected design storm and frequencies. When finished, click the **[Apply]** button.

Save your curves by clicking the **[Save]** button and specifying a name for your file. An ".pcp" extension will be applied. This file will automatically open each time you launch Hydrology Studio. You can, of course, change this file any time afterwards.

Click the **[Open]** or **[Save]** buttons to open or save an existing .pcp file.

4.1.2.1 Importing Precipitation

Rather than type in each and every rainfall value, Hydrology Studio offers a way to import this data directly into your precipitation table.

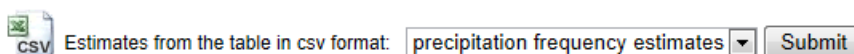
How to Import from NOAA

Provided your state is one which is listed on this atlas, you can quickly import this data by first exporting it from NOAA's Precipitation Frequency Data Server. To start, click the **[NOAA]** button on the Ribbon Toolbar to open the web server. Then select your state and follow the instructions. Be sure to set the Data type to "Precipitation Depth, Partial Duration" as shown below.

DATA DESCRIPTION

Data type: Units: Time series type:

At the bottom of the PF Tabular table you'll see an option to export as a .csv file.



Click **[Submit]**. The file will open in your web browser, or other text viewer, and will look similar to the following:

```
Point precipitation frequency estimates (inches)
NOAA Atlas 14, Volume 1, Version 5
Data type: Precipitation depth
Time series type: Partial duration
Project area: Southwest
Latitude (decimal degrees): 34.4000
Longitude (decimal degrees): -111.7000

PRECIPITATION FREQUENCY ESTIMATES
by duration for ARI:, 1,2,5,10,25,50,100,200,500,1000 years
5-min:, 0.24,0.31,0.42,0.51,0.64,0.74,0.85,0.97,1.15,1.29
10-min:, 0.37,0.48,0.65,0.78,0.97,1.13,1.30,1.48,1.75,1.97
15-min:, 0.46,0.59,0.80,0.97,1.21,1.40,1.61,1.84,2.17,2.44
30-min:, 0.62,0.80,1.08,1.30,1.62,1.89,2.17,2.48,2.92,3.28
60-min:, 0.76,0.98,1.33,1.61,2.01,2.34,2.69,3.07,3.61,4.06
2-hr:, 0.89,1.14,1.50,1.80,2.24,2.60,2.99,3.41,4.03,4.54
3-hr:, 0.98,1.24,1.59,1.90,2.33,2.68,3.07,3.50,4.12,4.63
6-hr:, 1.20,1.50,1.86,2.18,2.64,3.01,3.41,3.84,4.44,4.95
12-hr:, 1.49,1.85,2.27,2.62,3.09,3.46,3.85,4.23,4.79,5.26
24-hr:, 1.82,2.28,2.85,3.31,3.94,4.43,4.94,5.47,6.18,6.74
2-day:, 2.17,2.71,3.39,3.95,4.71,5.32,5.95,6.60,7.49,8.18
3-day:, 2.33,2.91,3.65,4.25,5.09,5.75,6.43,7.15,8.12,8.90
4-day:, 2.49,3.12,3.91,4.56,5.46,6.17,6.92,7.70,8.76,9.61
7-day:, 2.90,3.62,4.52,5.25,6.26,7.05,7.88,8.72,9.89,10.80
10-day:, 3.23,4.03,5.00,5.76,6.79,7.58,8.38,9.19,10.30,11.16
20-day:, 4.15,5.17,6.32,7.18,8.28,9.08,9.87,10.62,11.57,12.26
30-day:, 4.96,6.18,7.55,8.58,9.88,10.83,11.76,12.65,13.77,14.58
45-day:, 5.96,7.44,9.11,10.38,12.02,13.23,14.42,15.58,17.06,18.14
60-day:, 6.81,8.50,10.35,11.72,13.45,14.70,15.91,17.06,18.49,19.52

Date/time (GMT): Thu May 3 18:02:02 2012
pyRunTime: 0.0390179157257
```

Do not modify this file as Hydrology Studio is expecting it to be in this exact format. Save this file as a .txt or .csv file, preferably in your Hydrology Studio/Rainfall folder.

Next, click the **[Import]** button on the Hydrology Studio Precipitation Manager screen. Select the file you just saved and click **[Open]**.

Click **[Apply]**.

Save your curves by clicking the **[Save]** button and specifying a name for your file. A ".pcp" extension will be applied. This file will automatically open each time you launch

Hydrology Studio. You can, of course, change this file any time afterwards.

Click the **[Open]** or **[Save]** buttons to open or save an existing .pcp file.

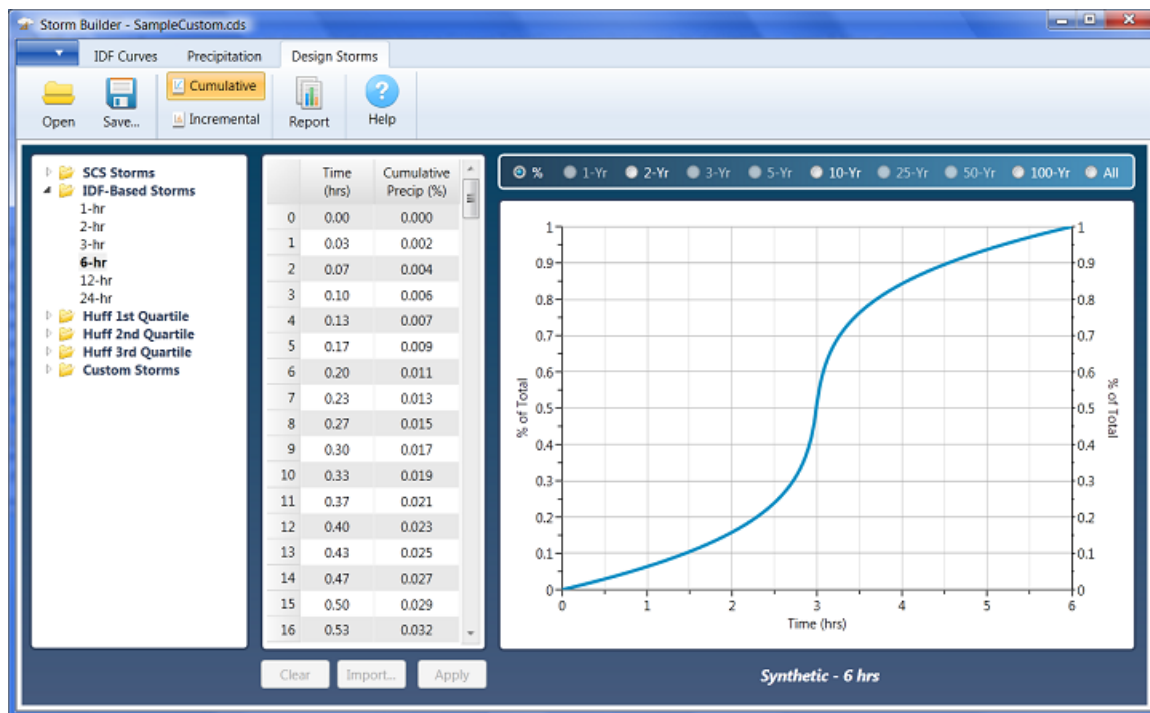
4.1.3 Design Storms

Hydrology Studio has a built-in library of ready-made design storms. They can be viewed from the "Design Storms" tab on the Rainfall IDF Wizard screen. The associated precipitations for these storms are entered in the "Precipitation" tab.

Storm Name	Duration (hrs)	Description
Type I, IA, II, & III	24	Dimensionless distributions developed by SCS using Weather Bureau's Rainfall Frequency Atlases for different geographic regions.
Type II Fla Mod	24	Type II modified for parts of Florida.
SCS Standard	6	Dimensionless distribution developed by SCS for a shorter, 6-hr duration
Synthetic, IDF-based	1, 2, 3, 6 12 & 24	Dimensionless distribution is automatically developed using current IDF curves and symmetrically arranged rainfall depths.
Huff, Bulletin 71. All Quartiles	Varies with Quartile	Developed from Time Distributions of Heavy Rainstorms in Illinois by Floyd A. Huff. Used primarily in the Midwest.
Custom	User-defined	A user-specified dimensionless storm. Up to ten unique storms can be entered.



To begin, click the **[Rainfall]** button on the Ribbon Toolbar to open the Rainfall IDF Wizard. Select the "Design Storms" tab on the Ribbon Toolbar. The Storm Builder screen should look like the following:



Use this screen to view the built-in design storms or enter custom distributions.
The current "Active" storm name is shown in bold text.

Design Storms can be selected for viewing by clicking on the storm name in the Tree View panel on the left. Note the highlighted storm is currently "Active". You can activate storms on the tree view by first selecting the storm and then right-clicking. Choose "Activate" on the pop-up menu. See [Precipitation & Events](#) for more information on activating storms.

Storms hyetographs can be viewed in either cumulative or incremental, as well as dimensionless precipitation ratios and actual events.



The built-in design storms are hard-coded and cannot be edited. Only the [Custom Storms](#) can be edited.

4.1.3.1 Custom Design Storms

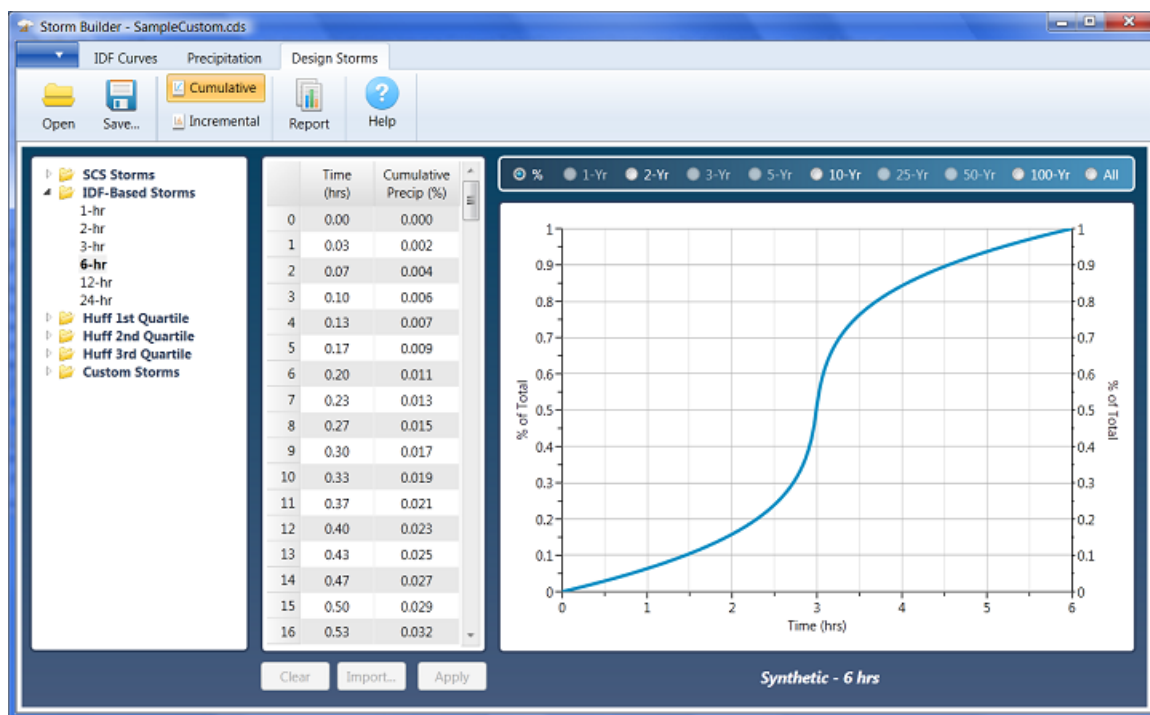
Hydrology Studio will allow you to directly input a precipitation distribution, like the SCS storms, that was perhaps created by an outside source such as your local drainage authority. Input requirements are the cumulative precipitation **ratios** for the desired duration. You can enter up to 2,880 precipitation ratios. These ratios should

begin at 0 and increase to 1.0 in the current Time Interval. If the Time Interval is later changed, Hydrology Studio will automatically interpolate custom storm distributions to match.

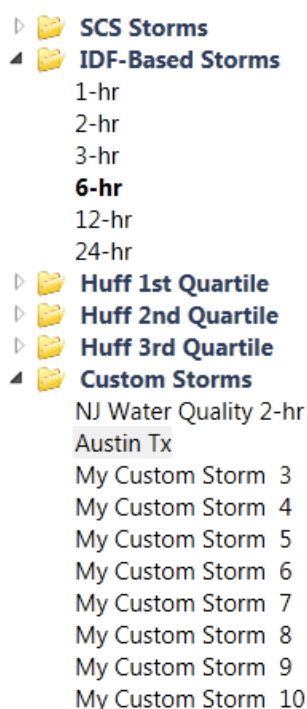
Here's an example:



To begin, click the **[Rainfall]** button on the Ribbon Toolbar to open the Rainfall IDF Wizard. Select the "Design Storms" tab on the Ribbon Toolbar. The Storm Builder screen should look like the following:



Next click on the "Custom Storms" folder on the Tree View panel.



Select one of the 10 available storms and begin entering precipitation ratios in the table to the right. Note that the Ratio option button (%) must be selected on the frequency selector in order to add/edit a custom storm. Values must begin at zero and increment up to 1.0. Hydrology Studio offers a way to import data from a text file. Please see [Importing Design Storms](#).



These ratios are applied to the corresponding precipitation amounts entered in the [Precipitation Manager](#).

When finished click the **[Apply]** button.

Adding a Name

To edit the name of the custom storm, double-click the name on the Tree View. Then click again. Type in the new name and click the **[Apply]** button.

4.1.3.1.1 Importing Design Storms

Design storms can be imported from existing files of type .txt, .csv or even legacy .cds.

File Format

The following format must be used:

Time Interval in minutes

Precip Ratio at Time Interval 1

Precip Ratio at Time Interval 2

Precip Ratio at Time Interval 3

Precip Ratio at Time Interval 4

Precip Ratio at Time Interval 5

.

.

Precip Ratio at Time Interval n (n<= 2,880)

Here is a sample file used for the NJ Water Quality Storm. It has a time increment of 5 minutes and a total duration of 120 minutes.

5
.0066
.0133
.02
.04
.06
.08
.1064
.1328
.16
.2066
.2866
.5
.7134
.7934
.84
.8672
.8936
.92
.94
.96
.98
.9867
.9934
1



Don't worry if the imported storm is in a time interval different from what is currently being used in Hydrology Studio. It will automatically convert the values using a straight-line interpretation.

To import, click the **[Import...]** button. Choose the file you wish to import and click **[Open]**. Hydrology Studio will populate the table with the precipitation ratios.

Click **[Apply]** to accept.

Save your storm(s) by clicking **[Save]** on the Ribbon Toolbar and specifying a name for your file. A ".cds" extension will be applied. This file will automatically open each time you launch Hydrology Studio. You can, of course, change this file any time afterwards.

Click the **[Open]** or **[Save]** buttons to open or save an existing .cds file.

4.2 Adding Runoff Hydrographs

Your basin model should always begin with a runoff hydrograph at the upstream end. There are three different types of runoff hydrographs you can use.

1. SCS/NRCS
2. Rational (includes Modified Rational)
3. Manual entry or imported

As shown in the [Quick Start Tutorials](#) in the Overview section, your basin model can be constructed and edited from any of the three tabs on the Main Window. Namely, Basin Model, Table or Charts. The procedure is basically the same from each tab.

Basin Model Tab - Click anywhere on the canvas to insure you don't have any existing hydrographs selected. Then click one of the three runoff hydrograph buttons on the Ribbon Toolbar. Hydrology Studio places the corresponding icon on the basin model. You can move the icon around as needed by dragging it with your mouse.

Table Tab - Click an unused or empty row on the grid. Then click one of the three runoff hydrograph buttons on the Ribbon Toolbar.

Charts Tab - Click on an unused row on the Hydrographs Listbox. Then click one of the three runoff hydrograph buttons on the Ribbon Toolbar.



While in the Table or Charts tab, you can select any of the unused hydrograph rows for your next hydrograph, but while in the Basin Model tab, it automatically assigns the next higher number available.

4.2.1 SCS Hydrographs

As described in the [Quick Start Tutorials](#), runoff hydrographs are added to your model by clicking one of the Runoff Hydrograph buttons on the Ribbon Toolbar at the Main Window. In this case, click the **[SCS]** button. After the icon has been added, simply click on its icon or row, depending on which tab you are working from, to populate its input window. Simply fill-in-the-blanks and click **[Compute]**.

Required Data

The following is a description of each of the required input items.

Name

Enter any descriptive name for this hydrograph. It will appear on the printed reports as well as the Basin Model.

Runoff Area

Enter the sub-basin area. No size limit.

Curve Number, CN

Enter the SCS Curve Number for this area. A table of CNs is available [here](#). For a composite CN, press the [%] button. Up to six sub-basin areas and corresponding CNs can be entered for a composite CN.

Time of Concentration, Tc

Tc is the time it takes for runoff to travel from the most remote upstream point in the drainage area to the downstream point in question. Select one of the four Tc options from the drop-down list box.

User - Check this option to override the computed Tc and enter Tc manually.

Lag - The TR-20 default method.

Kirpich - This method is normally used for natural basins with well defined routes for overland flow along bare earth or mowed grass roadside channels. It is similar to the Lag method but will typically give shorter times compared to the Lag method. Use this method when the subarea is dominated by channel flow.

TR55 - Compute Tc by using the built-in TR55 worksheet. [See Tc by TR55](#).

If you chose Lag, Kirpich or TR55, click the ellipsis [...] button to open the corresponding input screen. There, Tc will be computed and automatically inserted into the Tc input box.



One important component to the SCS hydrograph is the Shape Factor. It is assumed that all SCS hydrographs in a given project will use the same Shape Factor, typically 484. This value can become smaller in coastal regions. Check local ordinances. This value can be changed in the [Project Settings](#).

4.2.2 Rational Method Hydrographs

As described in the [Quick Start Tutorials](#), runoff hydrographs are added to your model by clicking one of the Runoff Hydrograph buttons on the Ribbon Toolbar at the Main Window. In this case, click the **[Rational]** button. After the icon has been added, simply click on its icon or row, depending on which tab you are working from, to populate its input window. Simply fill-in-the-blanks and click **[Compute]**.



Rational method hydrographs are best computed on 1-minute Time Intervals. The Time Interval can be changed in [Project Settings](#).

Required Data

The following is a description of each of the required input items.

Name

Enter any descriptive name for this hydrograph. It will appear on the printed reports as well as the Basin Model.

Runoff Area

Enter the sub-basin area. No size limit but watch for limits imposed by local ordinances, typically 20 acres.

Runoff Coefficient

Enter the Runoff Coefficient for this area. A table of coefficients is available [here](#). For a composite C, press the [%] button. Up to six sub-basin areas and corresponding Cs can be entered for a composite C.

Time of Concentration, Tc

Tc is the time it takes for runoff to travel from the most remote upstream point in the drainage area to the downstream point in question. Select one of the Tc options from the drop-down list box.

User - Check this option to override the computed Tc and enter Tc manually. Rational method Tc must be a whole multiple of the current Time Interval.

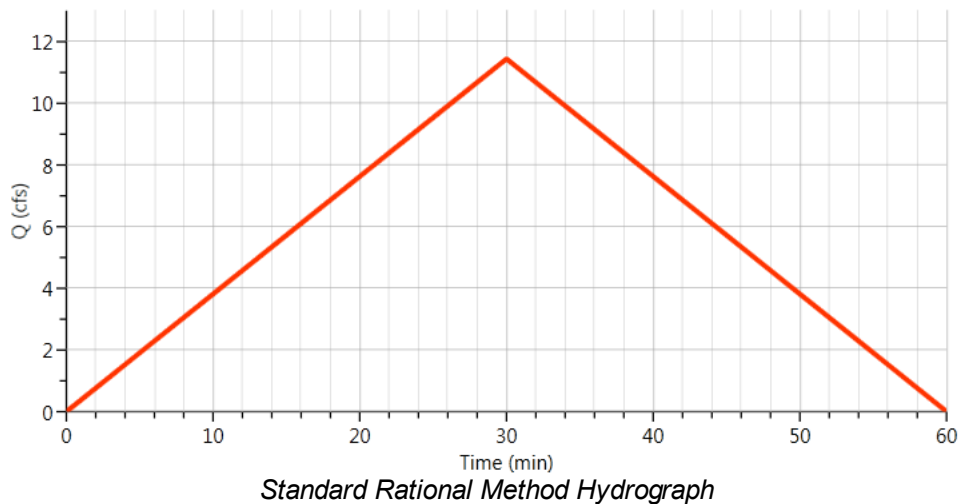
TR55 - Compute T_c by using the built-in TR55 worksheet. [See \$T_c\$ by TR55.](#)

If you chose TR55, click the ellipsis [...] button to open the TR55 input screen. There, T_c will be computed and automatically inserted into the T_c input box.

Calculation Method

Choose either the Standard Rational or Modified Rational from the drop-down list box.

The *Standard Rational* method simply computes the peak flow, $Q_p = C_iA$. The resulting hydrograph is an isosceles triangle.

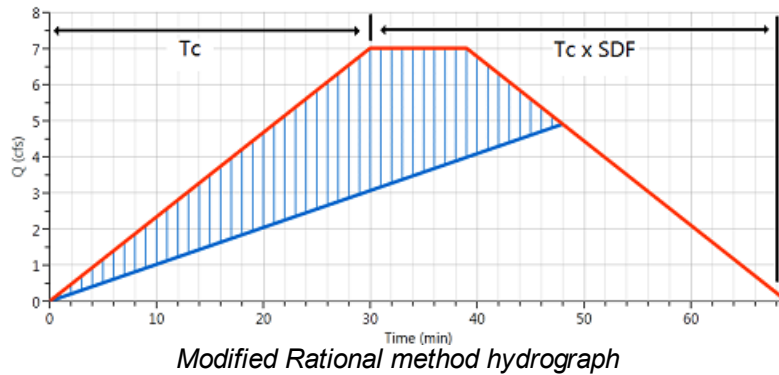


The *Modified Rational* method takes the Standard Rational to a different level in order to yield a hydrograph for use in detention pond design. According to the Rational method, the highest Q_p occurs when the rainfall duration equals T_c . When the rainfall duration is greater than T_c , the Q_p is reduced, but the total runoff volume is increased. This greater volume can increase the required size of a detention pond.

The objective is to find the total duration (critical storm event) that maximizes the required storage of a detention pond. The user simply modifies the Storm Duration Factor (SDF) between successive routings to arrive at the critical event. Luckily, Hydrology Studio automatically computes the SDF values for you. Simply plug in the Target Q_s . For example:

	Q_{target} (cfs)	SDF
2-yr	12.00	1.33
10-yr	18.00	1.50
100-yr	24.00	1.80

Storm Duration Factors (SDF) are automatically computed.



4.2.3 T_c by TR55

Hydrology Studio has a built-in TR55 worksheet that computes T_c. T_c is computed by adding the travel times of Sheet Flow, Shallow Concentrated Flow and Open Channel Flow from each of three components A, B and C, as described in Technical Release 55 (TR-55) Urban Hydrology for Small Watersheds. The individual data items are self explanatory however, a brief description of the flow types will be described below.

To use this feature, select the TR55 from the drop-down list box at the SCS Input Window. Then click the [...] button next to it.

Sheet Flow

Sheet flow is flow over plane surfaces usually in the upper reaches of the drainage area. A typical n-value used is .011 for smooth surfaces such as concrete, asphalt or bare soil. Dense grasses yield .24, Bermuda grass is .41 while woods range from .40 to .80 depending on the underbrush.



The Flow Length is limited to 300 feet per TR55 and 100 feet per WINTR55. After 300 feet, sheet flow turns to shallow concentrated flow.

Shallow Concentrated Flow

The average velocity is automatically computed and is based on the watercourse

slope and surface type - Paved or unpaved. This segment is best described as the surface between sheet flow and open channel flow.

Open Channel Flow

For these data items, it is assumed the channel is bank-full. Velocity is automatically computed.

You can enter data for up to 3 components for each flow type, areas A, B & C.

A hard copy worksheet report is available from the Reports menu.

When finished, click the **[Apply]** button and then **[Close]**. The program returns to the SCS Input Window and inserts the computed Tc value.

4.2.4 Adding Hydrographs Manually

There may be occasions when you'll need to specify a hydrograph by direct entry as it may have originated from other hydrology software or source. Hydrology Studio allows you to enter or import a hydrograph, one for each return period. To add a Manual Hydrograph, click the **[Manual]** button on the Ribbon Toolbar. After the icon has been added, simply click on its icon or row, depending on which tab you are working from, to populate its input window. Simply fill-in-the-blanks and click **[Compute]**.

Required Data

The following is a description of each of the required input items. Remember, it's easier to use the Tab key when navigating between input items.

Name

Enter any descriptive name for this hydrograph. It will appear on the printed reports as well as the Basin Model.

Return Period

Select a return period from the drop-down list.

Time vs. Outflow

The time units are already filled in using the current Time Interval. The Time Interval can be changed in [Project Settings](#) if needed. Simply type in the corresponding outflows for each time increment. Click **[Compute]** when finished. Repeat for each desired Return Period.

	Time (min)	Outflow (cfs)
0	0	0.00
1	2	0.00
2	4	0.00
3	6	0.00
4	8	0.00
5	10	0.00
6	12	0.00
7	14	0.00
8	16	0.00
9	18	0.00
10	20	0.00
11	22	0.00

Importing a Manual Hydrograph

A hydrograph can be imported from any .txt or .csv file. The imported file must be in the following format:

Time Interval in minutes

Q_0

Q_1

Q_2

Q_3

.

.

Q_n

Where: Time Interval = dt in minutes
 Q_n = Outflow at Time n minutes
 $n \leq 2,880$

A sample file with a 5-minute time interval which peaks at 50 minutes may look like this:

5

0

1

2
3
4
5
6
7
8
9
20
9
8
7
6
5
4
3
2
1
0

4.3 Adding Junctions

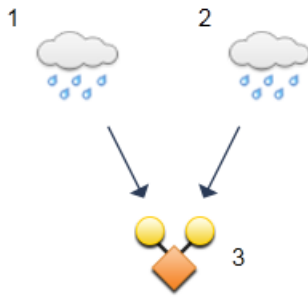
As shown in the [Quick Start Tutorials](#) in the Overview section, runoff hydrographs were combined at strategic locations. It is important to note that one of the underlying assumptions when creating runoff hydrographs is that the drainage areas are homogeneous, i.e., similar CNs, slopes, etc. When they are not it is best to break up the watershed into separate, homogeneous subareas, creating individual hydrographs and then add them together to form a junction. Hydrology Studio can combine up to six previously generated hydrographs at a time.

Here's an example:

To add or combine hydrographs, select them first by dragging a rectangle around them with your mouse or alternatively, click on the icons while holding down the **[Shift]** key. Then click the **[Junct]** button on Ribbon Toolbar.



Your model schematic will look like this:



After the icon has been added, simply click on its icon or row, depending on which tab you are working from, to populate its input window.

Required Data

The following is a description of each of the required input items.

Name

Enter any descriptive name for this hydrograph. It will appear on the printed reports as well as the Basin Model.

Select Inflow Hydrographs

Select the inflow hydrographs from the list box. These are pre-selected but can be edited at any time.



Only hydrographs with numbers less than your Junction Hydrograph number can be combined. Hydrograph numbers need to increase as you work downstream. The program maintains this numbering system for you and does so in order to properly construct the routing diagram.

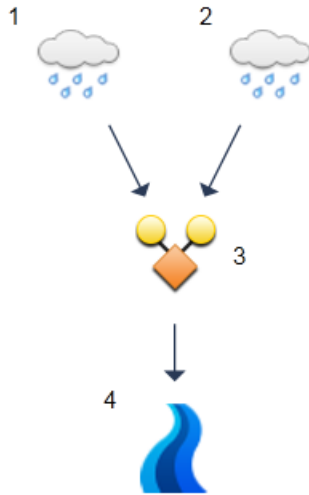
Click **[Compute]** when finished.

4.4 Routing Through Channels

Channel or Reach routing becomes necessary when your inflow hydrograph must travel through a substantially long and well-defined channel where the channel storage is expected to have a significant impact on attenuation of the hydrograph.

In many cases where the channel is small, less than 5 feet in width and/or has a travel time less than the time interval used, it will not be necessary to perform a channel route. That is, the hydrograph travels through the entire channel in less time than the Time Interval. In these cases it is recommended that the channel portion be included in the runoff hydrograph drainage subarea and T_c calculations.

To route a hydrograph, select the inflow hydrograph first by dragging a rectangle around it with your mouse or alternatively, click on the icon. Then click the **[Reach]** button on Ribbon Toolbar. A Reach icon will be added to your model. For example the following model shows hydrograph 3 as the inflow to a Reach, hydrograph 4.



Next, click on the Reach icon to populate its input window.

Required Data

The following is a description of each of the required input items.

Name

Enter any descriptive name for this hydrograph. It will appear on the printed reports as well as the Basin Model.

Inflow Hydrograph

The inflow hydrograph has already been selected but can be edited at any time. Just select from the drop-down list.



Only hydrographs with numbers less than your Reach Hydrograph number can be selected. Hydrograph numbers need to increase as you work downstream. The program maintains this numbering system for you and does so in order to properly construct the routing schematic.

Routing Method

Select your preferred calculation method from the drop-down list box. Your choices include Modified Att-Kin and Muskingum-Cunge. The Muskingum-Cunge method tends to give higher peak flow values than the Modified Att-Kin. See [Computational Methods](#) for more information.

Section Type

Select the type of section that best describes this channel section, Trapezoidal, Rectangular, Triangular or Circular.

Circular or pipe sections that flow full or higher are not recommended for this procedure. It is highly probable that detention storage would occur upstream and therefore would require a storage-indication reservoir routing procedure. In addition, Circular sections are not available when using the Muskingum-Cunge method.

If you want to directly enter known x and m values, select "Known x / m ". The remaining section data will not be required.

Reach Length

The total length of the reach.

Channel Slope (%)

The slope of the channel in percent, i.e., ft/100 ft

Manning's n

Select a roughness coefficient from the drop-down list. See [Useful Tables](#) for a look-up.

Bottom Width

Enter the width of the channel bottom. This is zero for Triangular sections. Note that the Modified Att-Kin method has a minimum bottom width of 5 feet.

Side Slope ($z:1$)

Enter the side slope of the channel in the ratio form, z (horizontal) to 1 (Vertical). Zero for rectangular sections.

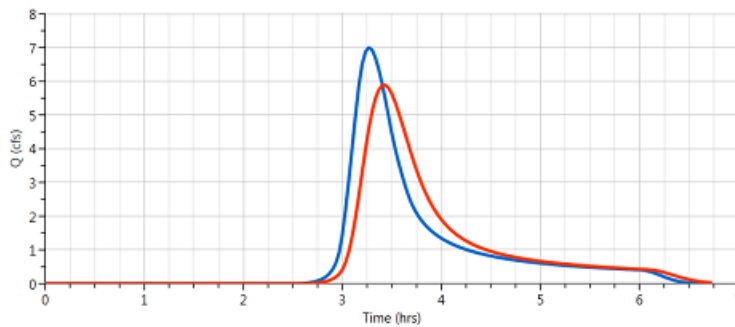
Maximum Depth

Enter the full-flow depth of this channel.

Coefficients x & m

This input section is skipped for section types other than "Known x/m " as well as the Muskingum-Cunge method. Enter the known x and m values. For more information on the x and m coefficients, see [Computational Methods](#).

Click **[Compute]** when finished.

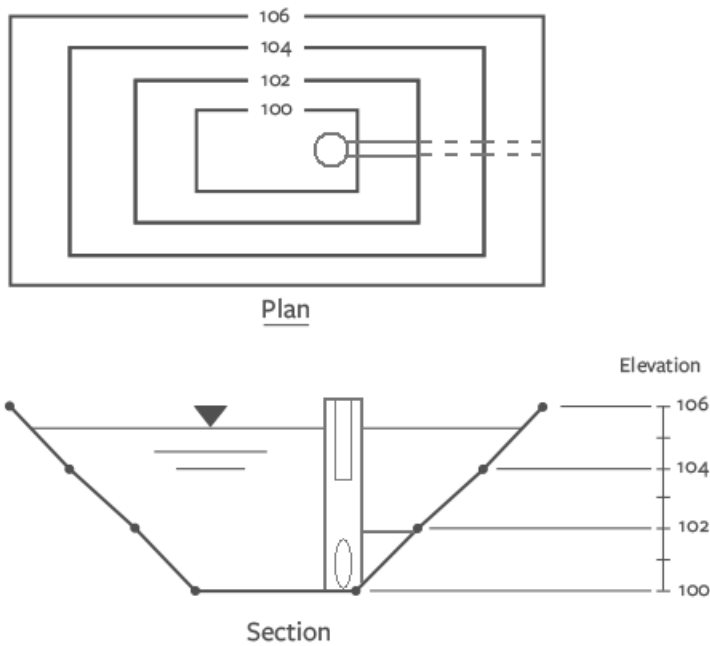


Typical channel route chart

4.5 Creating Detention Ponds

A primary function of Hydrology Studio is detention pond design and routing. This section describes how to set up a detention pond. Once set up you can route any existing hydrograph through it. You simply select the pond from a drop-down list on the Pond Rout Input Window. A maximum of 10 unique ponds can be set up for any given project. Each pond can contain a wide variety of outlet devices acting independently or in series as multi-stage configurations.

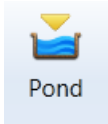
Since a Pond is not a hydrograph its icon is not displayed on the Basin Model.



Typical detention pond

An important thing to note is that a pond is merely a stage-storage-discharge relationship. It's basically a table of numbers that describe how your pond will perform when its water level reaches a given depth or stage. Similar to a pump performance curve, i.e., Head vs. Q. In this case, Stage vs. Storage and Stage vs. Discharge.

Creating a New Pond



To begin, click on the **[Pond]** button on the Ribbon Toolbar.

This opens the Pond Designer window. The Pond Designer is setup in a wizard-like way using just three steps.

Step 1 - Estimate Storage

Step 2 - Create Pond

Step 3 - Add Outlets



*These three steps are navigated back and forth using **[Back]** and **[Next]** buttons in the upper left corner of the Pond Designer window.*

Skip "**Step1 - Estimate Storage**" as this is optional and click the **[Next]** button. Please see [Estimate Storage](#) for more information.

Setting up your pond is now a two-step process.

[Step 2 - Create Pond](#)

[Step 3 - Add Outlets](#)

After you have completed Step 3, you are ready to route an inflow hydrograph through the new pond.

4.5.1 Step 2 - Create Pond

This screen allows you to choose a variety of methods for describing the physical aspects of your pond. To use a pond, select one from the drop-down list.

Pond Name

Please enter a name for this pond -- *Required!*

Storage Type

Each pond can utilize any of four unique storage types.

Contours	Manual
Trapezoid	UG Chambers

The screenshot shows the 'Pond Designer' application window. The title bar reads 'Pond Designer'. The menu bar includes 'Exit', 'Report', and 'Help'. The toolbar has '< Back', 'Step 2 - Create Pond', and 'Next >'. The main area is divided into two sections. The left section contains input fields: 'Pond No.' (set to '1 - Unused'), 'Pond Name' (empty), a storage type selector (showing 'Contours'), 'Bottom Elevation ft' (0.00), 'Voids (%)' (100.00), and 'Volume Calc' (Conic). The right section contains a table with 5 columns: 'Stage (ft)', 'Elevation (ft)', 'Contour Area (sqft)', 'Incr Stor (cuft)', and 'Total Stor (cuft)'. The table has 21 rows, numbered 0 to 20. The first row (0) has values 0.00 for Stage and Elevation. The rest of the rows are empty. At the bottom of the window are 'Clear', 'Apply', and 'Done' buttons.

Hydrology Studio offers four storage types

These storage types can be used in combination with each other. Below is a description of each.

[Contours](#)

[Trapezoid](#)

[Manual](#)

[UG Chambers](#)

Once you've entered data for the pond, click the **[Next]** button to proceed to adding outlets.

4.5.1.1 Contours

Hydrology Studio can accept up to 20 unique user-defined contours to describe a pond. They can be of any contour interval and the contour interval can vary along the way. The process calls for entering contour areas starting from the bottom of the pond and working upwards. The storage values are automatically computed using either the Average End Area method applied vertically or the Conic method.

To start, select the **Contours** button. Then double-click the **Bottom Elevation** input on the input window.

Required Data

The following is a description of each of the required input items.



Click the Help option button at the top of the input table to view a help diagram.

Bottom Elevation

Type in the elevation of the bottom of the pond.

Voids (%)

This value defaults to 100 and is useful for modeling gravel-filled trench drains. It allows for a reduction in storage due to gravel fills and such, but still allows the total surface area available for exfiltration calculations.

Volume Calculation

Select your preferred method of computing incremental storage from the drop-down list.

Average End Area or Conic Method

Please see, [Computational Methods](#) for more information.

Next, click the **[Apply]** button. This sets up the Stage-Storage input table for contour entries.

	Stage (ft)	Elevation (ft)	Contour Area (sqft)	Incr Stor (cuft)	Total Stor (cuft)
0	0.00	100.00	0	0.000	0.000
1					
2					
3					
4					
5					

Double-click the cell and type in the contour area. Click [Tab] to advance to the next cell. Most items are automatically filled in as defaults.

Stage

Type in the stage value. The first stage value is always 0 and will be skipped. Your first entry will be the first contour elevation.

Press the **[Tab]** key to move to the next column - Elevation.

Elevation

Type the elevation corresponding to this stage. In most cases the program computes this value and displays it as a default. Simply press **[Tab]** to accept and proceed to the next item.

Contour Area

Type the contour area corresponding to this stage.

Press the **[Tab]** key to move to the next row of Stage, Elevation and Contour.

Repeat typing in Stage, Elevation and Contour Areas until you have reached the top of your pond. It is always wise to provide a little extra depth to your pond.

Incremental Storage & Total Storage

Is automatically computed and displayed as a default. Note this item is zero at stage zero.

You are not required to enter data for all of the available 20 stages, but at least three are required. When you are finished entering data, click the **[Done]** button near the bottom of the table.

A completed input table will look similar to the following:

	Stage (ft)	Elevation (ft)	Contour Area (sqft)	Incr Stor (cuft)	Total Stor (cuft)
0	0.00	100.00	1,000	0.000	0.000
1	1.00	101.00	2,000	1,471	1,471
2	2.00	102.00	3,000	2,483	3,954
3	3.00	103.00	5,000	3,957	7,911
4	4.00	104.00	8,000	6,441	14,352
5	5.00	105.00	11,500	9,696	24,049
6	6.00	106.00	15,000	13,210	37,259
7	7.00	107.00	18,000	16,476	53,734
8	8.00	108.00	24,000	20,926	74,660
9					
10					

Remember to click [Done] when finished!

See this data in a [3D surface chart](#).

4.5.1.2 Trapezoid

This storage type assumes you will be creating a pond that is rectangular in shape, has a known bottom area at stage zero, has equal side slopes (h:1) on all 4 sides and a desired maximum depth. It automatically computes the stage storage table based on the following input items.

To start, select the **Trapezoid** button. Then double-click the **Bottom Elevation** input on the input window.

Required Data

The following is a description of each of the required input items.



Click the Help option button at the top of the input table to view a help diagram.

Bottom Elevation

Type in the elevation of the bottom of the pond.

Bottom Length

Enter the bottom length.

Bottom Width

Enter the bottom width.

Side Slope

Enter the side slope as a ratio. Example: For a 3 to 1 (horizontal to vertical) side slope, enter 3.

Total Depth

Enter the total depth of the pond. This number should include any freeboard.

Voids (%)

This value defaults to 100 and is useful for modeling gravel-filled trench drains. It allows for a reduction in storage due to gravel fills and such, but still allows the total surface area available for exfiltration calculations.

Click **[Apply]** when finished.

A completed output table will look similar to the following:

	Stage (ft)	Elevation (ft)	Contour Area (sqft)	Incr Stor (cuft)	Total Stor (cuft)
0	0.00	100.00	500	0.000	0.000
1	0.50	100.50	594	273	273
2	1.00	101.00	696	322	595
3	1.50	101.50	806	375	970
4	2.00	102.00	924	432	1,403
5	2.50	102.50	1,050	493	1,896
6	3.00	103.00	1,184	558	2,454
7	3.50	103.50	1,326	627	3,081
8	4.00	104.00	1,476	700	3,781
9	4.50	104.50	1,634	777	4,558
10	5.00	105.00	1,800	858	5,417
11	5.50	105.50	1,974	943	6,360
12	6.00	106.00	2,156	1,032	7,392
13	6.50	106.50	2,346	1,125	8,517
14	7.00	107.00	2,544	1,222	9,739
15	7.50	107.50	2,750	1,323	11,062
16	8.00	108.00	2,964	1,428	12,491
17	8.50	108.50	3,186	1,537	14,028
18	9.00	109.00	3,416	1,650	15,678
19	9.50	109.50	3,654	1,767	17,445
20	10.00	110.00	3,900	1,888	19,333

Results of a 25 ft by 20 ft w/ 2:1 side slopes @ 10 ft depth

Note that you cannot edit the Trapezoid output table. You must edit the values in the input grid.

See your data in a [3D surface chart](#).

4.5.1.3 Manual Storage

This storage option allows you to enter stage, elevation and total storage values manually. Contours and incremental storage are not required. To use this feature, select **Manual** from the storage options.



Ponds created using Manual Entry cannot use exfiltration as a discharge as there is not a contour or surface area to apply it to.

Required Data

The following is a description of each of the required input items.

Bottom Elevation

Enter the elevation of the bottom of the pond.

Voids (%)

This value defaults to 100 and is useful for modeling gravel-filled trench drains. It allows for a reduction in storage due to gravel fills and such, but still allows the total surface area available for exfiltration calculations.

Click **[Apply]** when finished. This sets up the Stage-Storage input table for storage entries.

	Stage (ft)	Elevation (ft)	Contour Area (sqft)	Incr Stor (cuft)	Total Stor (cuft)
0	0.00	100.00	n/a	0.000	0.000
1	1.00				
2					
3					
4					
5					

Manual entry table. Note contour areas are not required.

Stage

Type in the stage value. The first stage value (Row 0) is always 0 and will be skipped. Press the **[Tab]** key to move to the Elevation column.

Elevation

Type the elevation corresponding to this stage. In most cases this value is displayed as a default. Simply press **[Tab]** to accept and proceed to the next item.

Total Storage

Total Storage at stage zero must be zero. Type in the value and press **[Tab]** to advance to next stage. You are not required to enter data for all of the available stages, but at least 3 are required.

When you are finished entering data, click the **[Done]** button near the bottom of the table.

4.5.1.4 UG Chambers

This option is used for underground storage chambers in the shape of circular, arch or rectangular vessels laying either flat or on a slope. Headers as well as a stone encasement are optional. Hydrology Studio will automatically calculate storage volumes for you based on a given chamber size, shape, slope and length.

To start, select the **UG Chambers** button. Then double-click the **Invert Elevation Down** input on the input window.

Required Data

The following is a description of each of the required input items.



Click the Help option button at the top of the input table to view a help diagram.

Invert Elevation Down

Enter the elevation at the lowest point in the chamber. If an encasement is not used, this will be stage zero.

Chamber Rise

Enter the diameter or height of the of the chamber vessel.

Chamber Shape

Specify Arch, Circular or Box.

Chamber Span

Enter the width of the chamber vessel.

Chamber Length

Enter the length, single barrel, of the chamber.

No. Barrels

Enter the number of chamber runs or barrels. In the Help diagram, there are five.

Barrel Slope (%)

Enter the slope of this pipe in percent.

Headers

This option will add connecting header chambers at the upstream and downstream ends. They are assumed to have the same shape and size as the primary chambers. Check the box to add headers.

Stone Encasement

Check the corresponding box to indicate stone encasement is being used.

Bottom Elevation

Enter the elevation of the encasement bottom. This must be equal to or below the chamber Invert Elevation Down.

Width per Chamber

Enter the encasement width for a single barrel. Must be greater than or equal to the chamber Span. The total encasement width will be computed as (Width per Chamber x No. Barrels).

Depth

Enter the depth of the encasement.

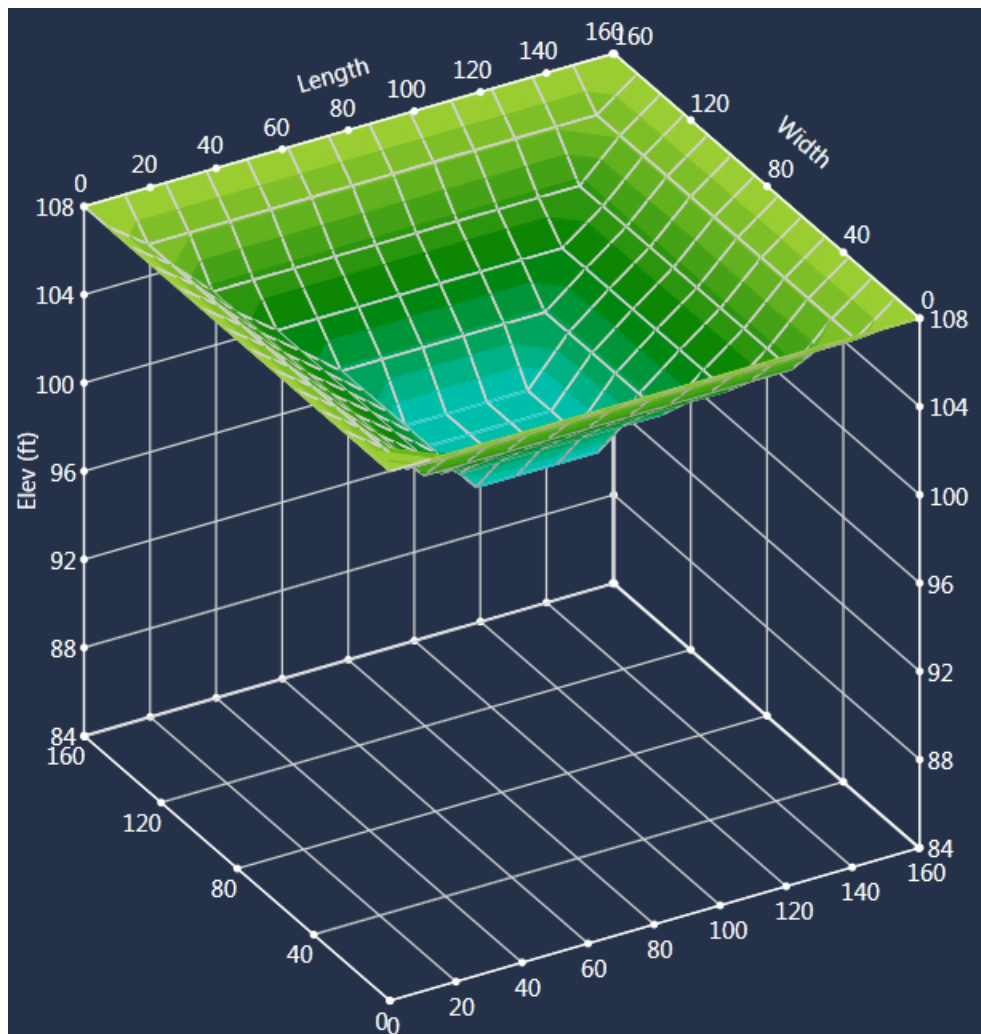
Voids (%)

This value defaults to 100. It allows for a reduction in storage due to a gravel-filled encasement.

Click **[Apply]** when finished.

4.5.1.5 Surface Charts

Hydrology Studio provides a 3-dimensional surface chart of your pond storage. This feature allows you to see your pond data in 3D while confirming your inputs. Just select the Surface Chart option button on the to section of the input table. A slider bar allows you to rotate and flip the drawing.



View your pond in 3D. Use the slider bar to rotate and flip.



Surface charts are not available for UG Chambers or Manual Storage types.

4.5.2 Step 3 - Add Outlets

This step completes the stage - storage - discharge relationship. Here, you'll specify the outlets which in turn generate discharge values corresponding to the stage values entered in the previous step.

Hydrology Studio has several unique outlet structures to choose from.

Culvert - Can be circular (Rise = Span) or rectangular with multiple barrels.

Orifice - *Up to three, circular (Rise = Span) or rectangular.*

Riser Weir - *Used for multi-stage structures.*

Weirs - *Up to three. Can be Rectangular, Cipoletti, V-notch, Broad Crested or Compound.*

Perforated Riser - *A stand-alone riser with perforations.*

Exfiltration - *Water exiting the pond as a rate which is applied to contours. Can automatically be extracted from routed outflow hydrograph.*

User-defined - *Directly enter known discharges.*

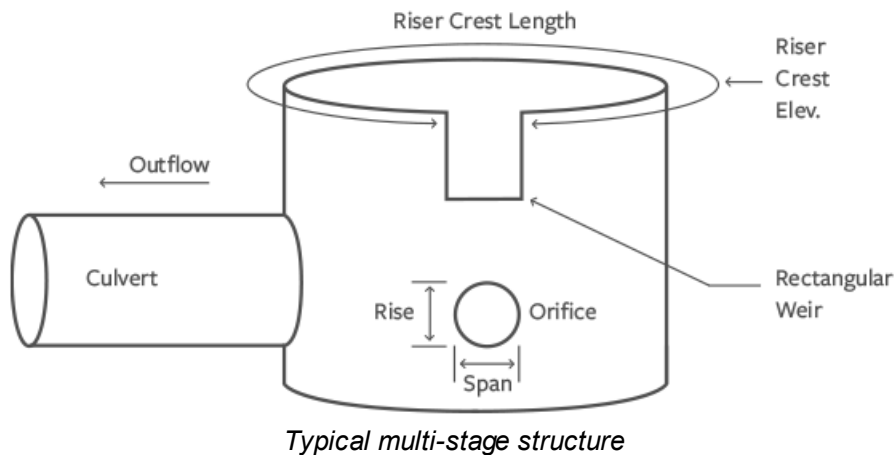
Tailwater - *Doesn't contribute to but can affect outflow. A single tailwater elevation can be specified.*

In computing the outflows, Hydrology Studio treats the discharges from these outlet structures as a function of stage or water surface elevation. Partial and full flow conditions are computed as well as inlet and outlet control and submergence.

About Multi-Stage Configurations

Unless the multi-stage option is checked on, each outlet structure is treated independently. This option puts the structures in series, thereby creating a multi-stage structure. This causes the outflows from that device to route through the Culvert. The structure with the least capacity at any given stage will control the final outflow. The Culvert is always the final outflow device so it does not have a multi-stage option.

The structure shown below contains a culvert with a riser, rectangular weir and orifice indicated as multi-stage.



When using the multi-stage option, Hydrology Studio checks the head elevation produced by the Culvert. This head is then used as a tailwater elevation against other multi-stage devices. As this head increases, the outflows from the orifice(s) and weir(s) decrease. When this head equals the current stage, the Culvert becomes the controlling structure and contributing flows from the orifice(s) and weir(s) diminish.

Adding Outlet Devices

You may add any combination of outlet devices to your pond but you may have only one of each. To add a device click on the button corresponding to the device. For example, click the Culvert button to add or edit an existing culvert.

Culvert	Riser	Orifice ▼	Weir ▼
Exfiltration	User	Perf Riser	Tailwater

Outlet Device Selector

Hydrology Studio will populate the Input Window with the appropriate input items. Select the Help Option button on the top of the output table to see helpful input diagrams of the outlet structure. Simply fill in the blanks and click **[Add/Update]** button. The output table on the right will be updated with the new stage-discharge data.

Editing Outlet Devices

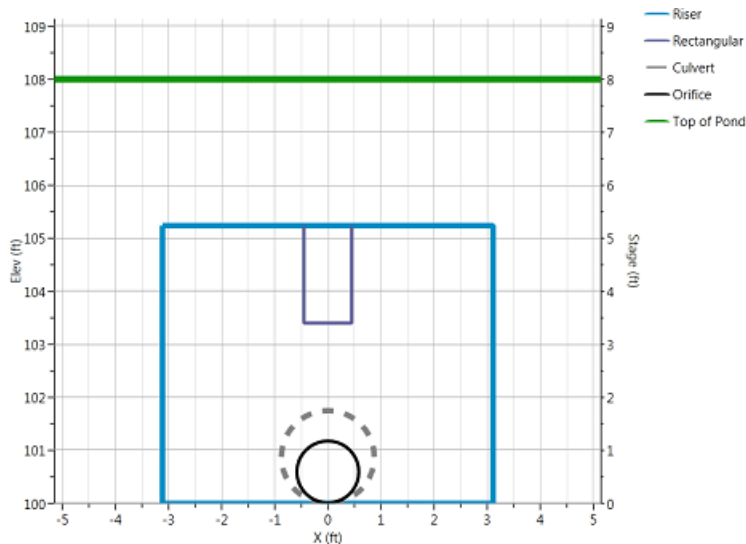
Edit any existing outlet device by selecting it from the Outlet Device Selector. Alternatively, click on the column corresponding to the device on the outlet table.

☒ Table ☐ Schematic ☐ Stage vs. Q ☐ Help							
	Stage (ft)	Elev (ft)	Storage (cuft)	Culvert (cfs)	Riser (cfs)	Orifice 1 (cfs)	Weir 1 (cfs)
	0.00	1000.00	0.000	0.00	0.00	0.00	0.00
	0.04	1000.04	33.0	0.00 ic	0.00	0.00 ic	0.00

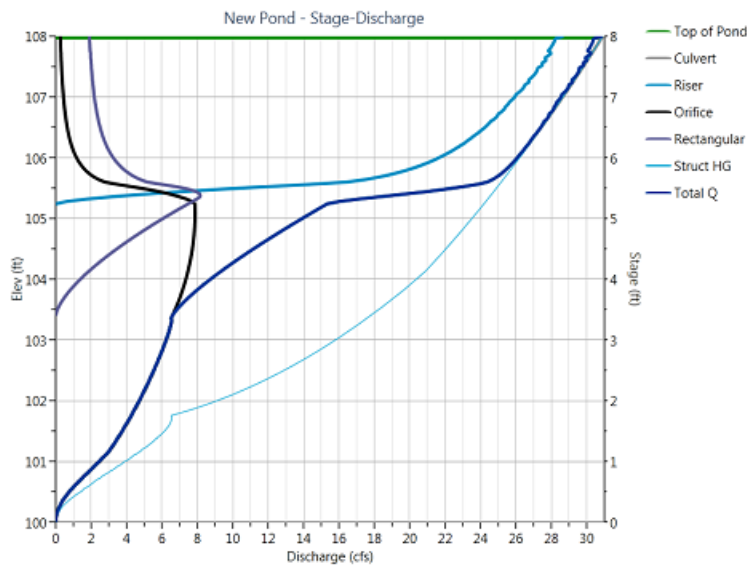
Click on the outlet column to edit

4.5.2.1 Stage vs. Q Chart

You can view your outlet data at any time by selecting the Stage vs. Q option button on the top of the output table. The outflows from the individual structures can be toggled on or off as well as the Structure HG, Total Q and Target Qs. The screen shot below shows a multi-stage device with all structures turned on.



Multi-stage structure schematic



The Riser is flooded when the Structure HG line merges with Total Q

When using the multi-stage option, Hydrology Studio checks the head elevation produced by the Culvert. This head is then used as a tailwater elevation against other multi-stage devices. As this head increases, the outflows from the orifice(s) and weir(s) decrease. When this head equals the current stage, the Culvert becomes the controlling structure and contributing flows from the orifice's and weirs diminish. The chart above explains this in graphic detail.

It's important to notice how the flows from the Orifice and Rectangular Weir diminish around elevation 105.5. This indicates that the Riser is filling up due to backwater head produced by the Culvert. The light blue line is the Structure HG and indicates the depth of water inside of the Riser. When this line merges with the Total Q line, the Culvert is the controlling structure. This occurs at approximately elevation 106.

4.5.2.2 Using Trial Route Feature

Setting up detention ponds can be difficult. In part because you can enter data but really not know the outcome of the routing until the routing was actually performed. At best it's a two-part trial & error process. The Trial Route feature brings the two parts closer by giving you the ability to add and modify outlet structures while doing the routing, in real time, dramatically reducing time spent on design.

It begins by estimating required the storage. As demonstrated in the Quick Start Tutorial, [Pre- and Post-development Model](#), Hydrology Studio hosts a feature which estimates storage requirements for a proposed detention pond. This is accomplished by specifying an inflow (post-developed) hydrograph and target outflows. These can be specified by either indicating a pre-developed hydrograph or by direct entry. Please see [Estimate Storage](#) for a quick tutorial.



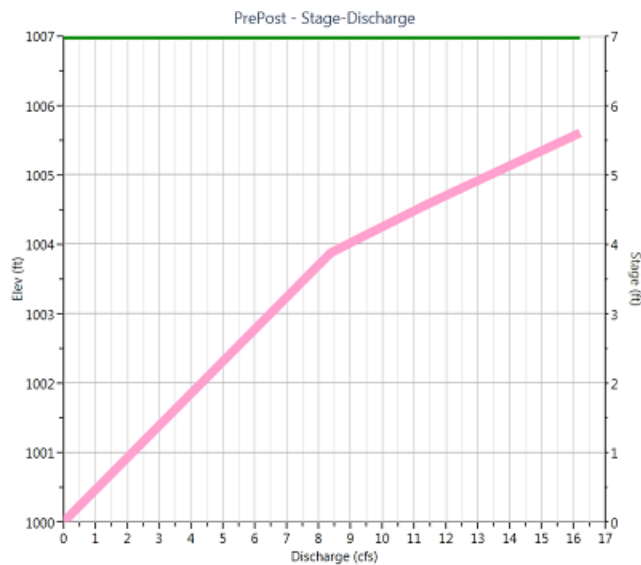
The Trial Route feature is only available when Step 1 - Estimate Storage has been completed.

Once the storage has been estimated and your pond has been sized to match, (See [Create Pond](#) in the same tutorial) Hydrology Studio develops a Target Stage-Storage-Discharge curve for you to use as a guide in selecting your outlet devices. This curve appears on the Stage vs. Q chart as a large pink line as shown below. You'll also notice the appearance of the Trial Route window just below the outlets Input Window.

	Q Target (cfs)	Q Actual (cfs)	Max Elev (ft)	Max Stor (cuft)
2-yr	8.39			
10-yr	11.44			
100-yr	16.21			

☐ Auto Route

Trial Route



Target Stage-Discharge. Your goal is to create an actual Stage-Discharge curve to match this.

Our objective is to create an actual Stage-Discharge curve which matches the target. This can be accomplished by selecting outlet structures, one-by-one, and making adjustments until the actual Stage-Discharge curve matches the target. Use the Trial Route window to perform routings. When the Auto Route check box is checked,

routings will be executed immediately after clicking **[Add/Update]**.

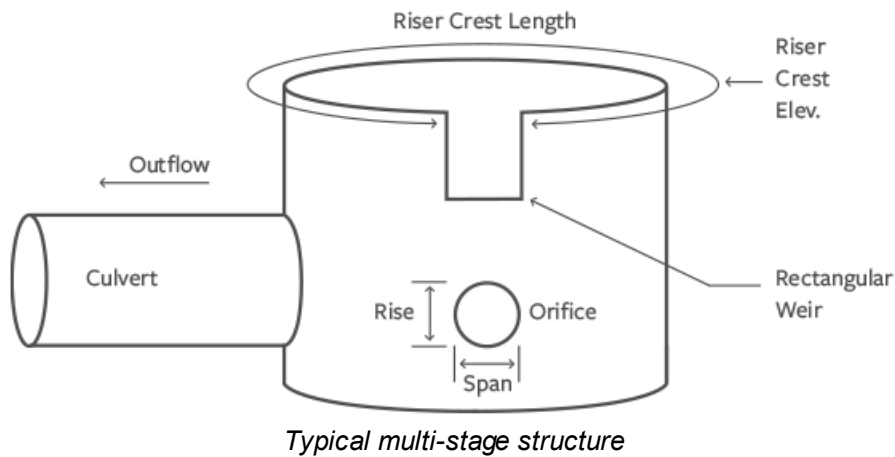
Tips and Best Practices for Multi-stage Ponds

Generally when designing multi-stage outlets, you'll need a device for each frequency you wish to model. For example, a 2-, 10 and 100-year model will most likely need a culvert, orifice and secondary weir. While it is possible to satisfy all frequencies with fewer devices, it's not very probable.

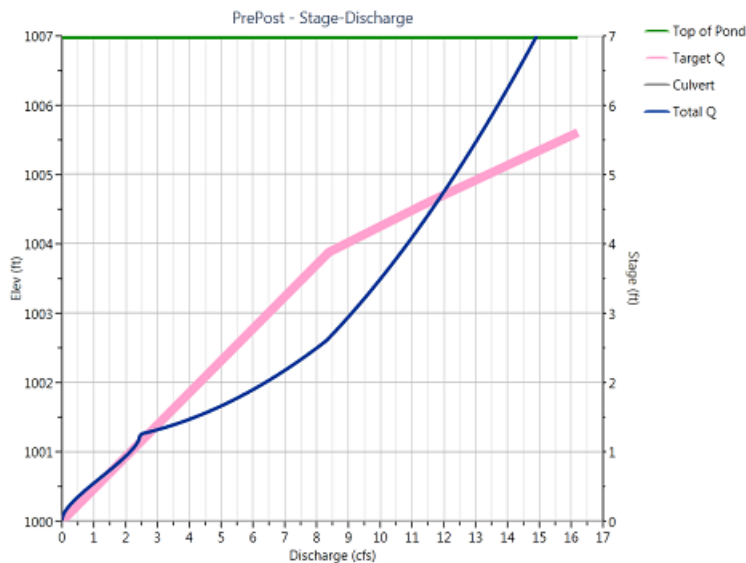
1. Always start a pond design by adding the Culvert first. Ideally it is this device that will control the final outflow. Plus, all other structures (Except an emergency spillway) route through this anyway. Size the Culvert to meet or exceed the upper end of the Target Curve. If the culvert outflow far exceeds the target Q, then you should plan on using secondary structures to satisfy this upper end. Perform a trial route to confirm. Use standard, commercially available sizes.
2. Next, add the lower return period devices such as an orifice to satisfy the lowest Target Q. Perform trial routes to determine the maximum elevation reached. Use this elevation as the invert for the next structure.
3. Next, add a secondary weir or orifice to satisfy the intermediate frequency(s). Perform trial routes to determine the maximum elevation reached. Use this elevation as the invert for the next structure. Repeat this step for each intermediate frequency. Experiment with v-notch as well as rectangular weirs.
4. Add a Riser structure to contain the multi-stage devices. Note that it is not recommended to use a Riser as a controlling device. Use it simply as a container for other devices such as orifices and weirs. Set the Riser crest elevation to just above the maximum elevation reached in Step 3.
5. Add any necessary emergency spillway weirs. Not multi-stage.

Example

The curve above was taken from the Quick Start Tutorial Pre- and Post Development Model just before the Add Outlets Step. Picking up from there, we'll go through the steps taken that accomplished that goal. Recall the target Qs of 8.4, 11.44 and 16.21 for the 2-, 10 and 100-yr return periods respectively. We configured this structure:



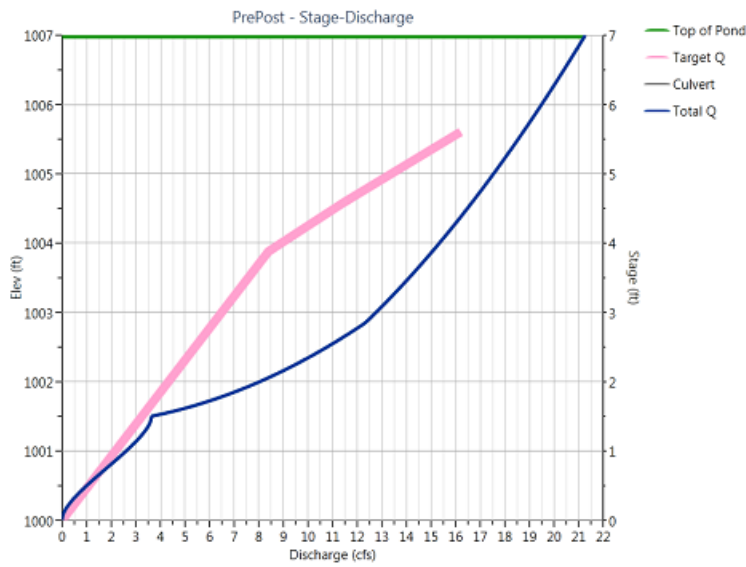
Step 1 - Add a 15-inch culvert and set the slope to .5% and the length to 25 feet. Click **[Add/Update]**.



Attempting to match the 100-yr target but missed

As you can see, the maximum flow produced by the 15-inch is insufficient at about 13 cfs.

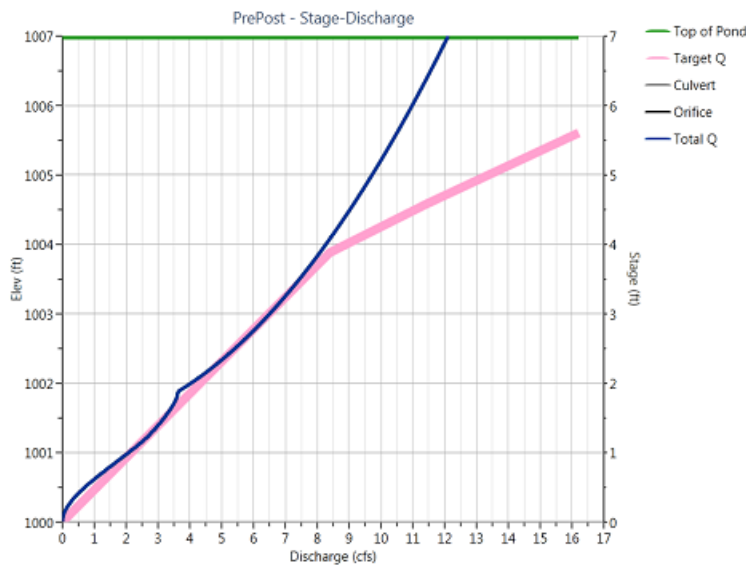
Increase the size to 18-inches to produce the following.



Close enough

This exceeds the target Q of 16.21 by about 2 cfs so we'll need to use a secondary device to control the upper frequency.

Step 2 - Add device for lower frequency. An educated guess adds a 15-inch orifice at elevation 1000.01. Don't forget to check Multi-stage on. Click **[Add/Update]**.



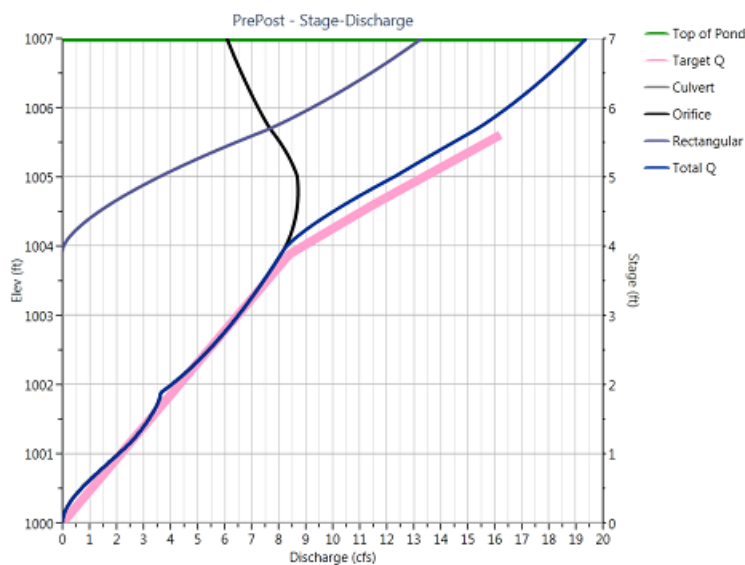
Perfect!

Click **[Trial Route]** and check the results.

	Q Target (cfs)	Q Actual (cfs)	Max Elev (ft)	Max Stor (cuft)
2-yr	8.39	8.11	1003.90	5,656
10-yr	11.44	9.78	1005.04	8,274
100-yr	16.21	11.82	1006.74	13,145

The Q actual for the 2-year is close enough. The Max Elev = 1003.90.

Step 3 - Add a secondary rectangular weir with a crest elevation at 1003.95. Try a "Best guess" crest length of 1.0. Don't forget to check Multi-stage on. Click **[Add/Update]**. Then click **[Trial Route]**.



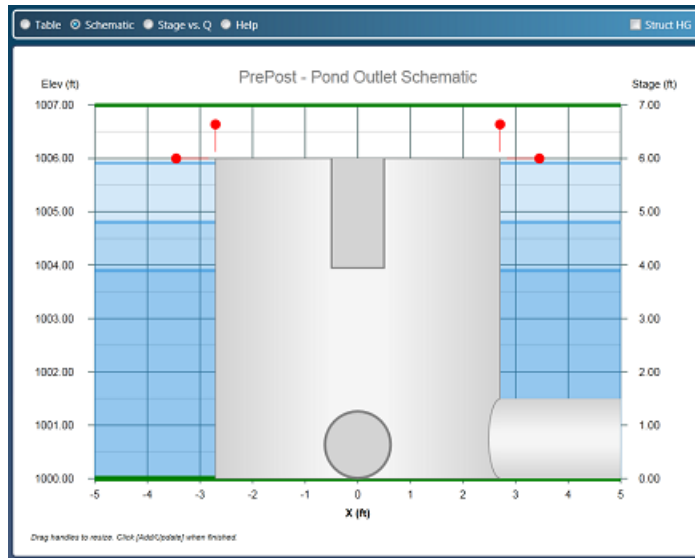
That worked!

	Q Target (cfs)	Q Actual (cfs)	Max Elev (ft)	Max Stor (cuft)
2-yr	8.39	8.11	1003.90	5,656
10-yr	11.44	11.36	1004.81	7,697
100-yr	16.21	16.19	1005.92	10,640

The Total Q follows the Target Q line and the trial routing assures us the target Qs are met. What's more is that the secondary rectangular weir satisfies both 10- and 100-year events!

Step 4 - Add Riser structure. Set the crest elevation to 1006.00. Since we don't want the riser structure to control flows, we want to make sure that its crest length is large enough to avoid this. A "best guess" is 4 ft on each side, say 16 ft. Click **[Add/Update]**. You shouldn't see any changes in the Total Q line. The Riser crest length can be adjusted down if desired.

Now that the outlets are designed, take a look at the schematic by selecting the Schematic option button on top of the output table. It should look like this:

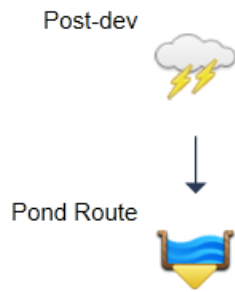


You can click on any structure to edit. Double-clicking allows you to graphically edit the structure by dragging resize handles. Be sure to click the **[Add/Update]** button when done editing.

4.6 Routing Through Detention Ponds

Even though you may have used the Trial Route feature in the Pond Designer, you'll need to perform the *real* routing back at the Main Window. Once you have set up at least one pond, you can route any existing hydrograph through it. You may specify only one inflow hydrograph. If more than one needs to enter the pond, combine them using the [Junction](#) process first.

To route a hydrograph, select the inflow hydrograph first by dragging a rectangle around it with your mouse or alternatively, click on the icon. Then click the **[Route]** button on Ribbon Toolbar. A Route icon will be added to your model similar to the following:



Next, click on the Route icon to populate its input window.

Required Data

The following is a description of each of the required input items.

Name

Enter any descriptive name for this hydrograph. It will appear on the printed reports as well as the Basin Model.

Inflow Hydrograph

The inflow hydrograph has already been selected but can be edited at any time. Just select from the drop-down list.

Pond Name

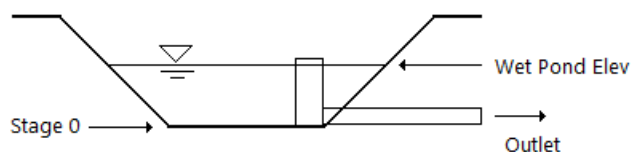
Select the pond you wish to use for this routing from the drop-down list. You can edit this pond directly by clicking the adjacent ellipsis [...] button.

Lower Pond

Hydrology Studio can route an inflow hydrograph through two interconnected ponds. Check this box to enable and select the lower pond from the drop-down list. This pond cannot be the same as the Upper Pond. See [Interconnected Pond Routing](#).

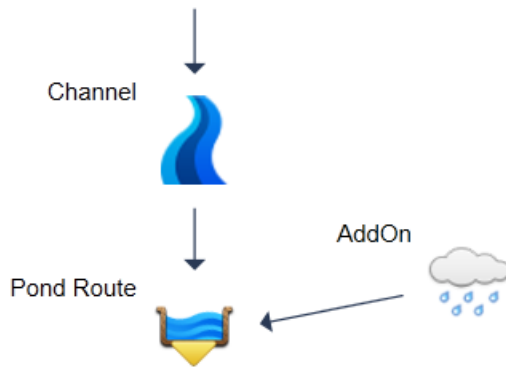
Wet Pond Elevation (not applicable to interconnected ponds)

This feature allows you to route through a pond which has a pre-set amount of water in it. Select this water surface elevation from the drop-down list. Note that there cannot be outflow from the pond at this chosen wet pond elevation.

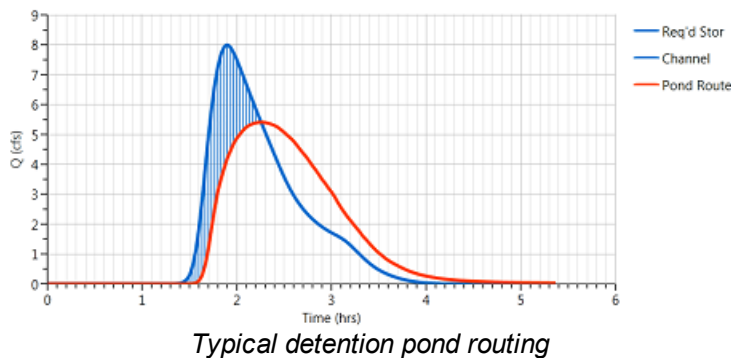


Additional Inflow (applicable to interconnected ponds only)

You can choose an additional inflow hydrograph to be added to the **Lower Pond**. Select the hydrograph from the drop-down list. The inflow hydrograph must have a number greater than the primary inflow hydrograph and less than the outflow, routed hydrograph.



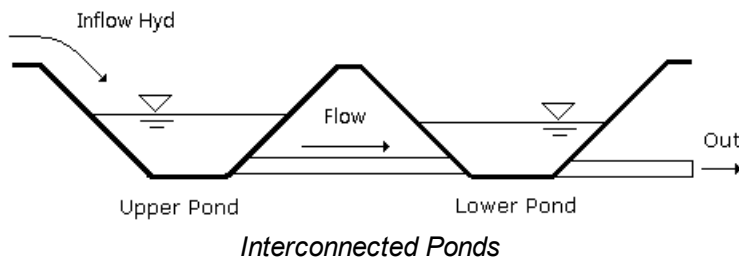
Click **[Compute]** when finished.



4.6.1 Interconnected Pond Routing

Hydrology Studio can route any hydrograph through two connecting, or "interconnected" ponds. Keep in mind that a routed outflow hydrograph from an upstream pond can simply be used as the inflow hydrograph into the second pond. You simply do two separate routings and not do an interconnected pond routing.

However, if the downstream pond is at or near the same bottom elevation as the upper pond that can affect the stage-discharge relationship of the upper pond. This in turn will affect the outflow hydrograph from the upper pond. This scenario rarely affects the final outflow hydrograph from the lower pond.

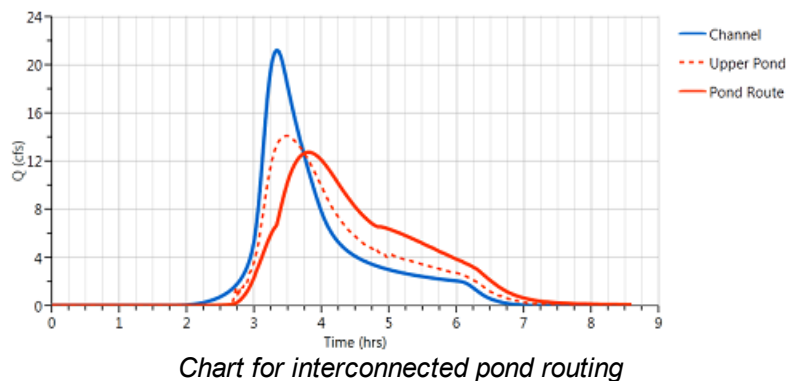


Calculation Procedure

The routing process is accomplished by dynamically linking the two ponds together. The routing calculation procedure is done in single time increments (equal to the project Time Interval). During this procedure, the outflow from the upper pond, over one time increment, is in turn routed through the lower pond. The computed stage in the lower pond is then used as a tailwater for the upper pond for the next calculation increment. Its stage-discharge curve is recomputed. No interpolation from the original Stage-Discharge curve. A new outflow is computed from the upper pond and the process is repeated for the remaining time increments. Thousands of detailed computations take place during this procedure. Hydrology Studio's fast and highly structured source code is demonstrated.

Although the program computes two hydrographs during this procedure, only the Lower Pond outflow hydrograph is available for further downstream processing. The Upper Pond hydrograph is attached to the lower (primary) hydrograph and will appear on all reports, graphs etc.

Only two ponds can be interconnected at once.

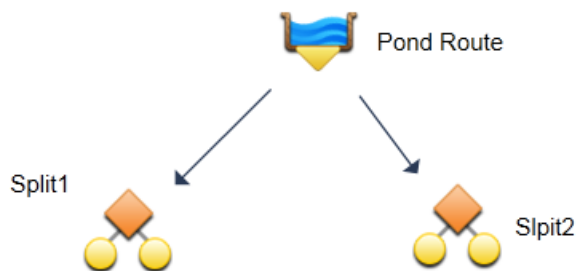


4.7 Diverting Hydrographs

Hydrology Studio can divert any hydrograph into two separate hydrographs. This will be useful during situations when channels divide or when pond outlet structures such

as an emergency spillway are designed to redirect the outflow. Diverting will become necessary if you need to strip off a "First-Flush" volume before allowing the remaining hydrograph to enter a detention pond.

To divert a hydrograph, select it first by dragging a rectangle around it with your mouse or alternatively, click on the icon. Then click the **[Divert]** button on Ribbon Toolbar. Two new Diversion icons will be added to your model. For example the following model shows a Pond Route hydrograph split into two.



Click on one of the two icons or row, depending on which tab you are working from, to populate its input window.

Required Data

The following is a description of each of the required input items.

Divert-1 Name & Divert-2 Name

Enter any descriptive name for each outflow hydrograph. They will appear on the printed reports as well as the Basin Model.

Inflow Hydrograph

Select the inflow hydrograph from the list box. Was pre-selected but can be edited at any time.

Choose Your Diversion Method

1. Constant Q

Use this method to divide the hydrographs by a constant flow rate. For example, an entry of 15 would generate a hydrograph, Divert-1, consisting of all Q's up to 15 and a second one, Divert-2, consisting of all Q's above 15.

2. Flow Ratio

This method divides the inflow hydrograph by a ratio. An entry of 0.75 generates a hydrograph, Divert-1, with flows equal to 75% of the inflow ordinates and a second one, Divert-2, consisting of the remaining 25% flow ordinates.

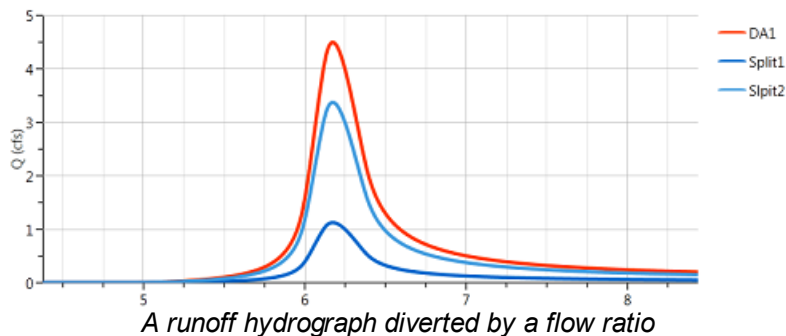
3. First Flush Volume

This feature allows you to strip off an initial volume from the inflow hydrograph. For example, if your detention pond contains a fore bay, you could extract that volume from the inflow hydrograph first. Set it aside and route the remaining hydrograph through the pond. Divert-2 would be the remaining hydrograph. Divert-1 is the fore bay volume.

4. Pond Structure

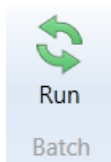
Provided the inflow hydrograph is a "Pond Route", you'll have the added option of dividing the hydrograph by one of the pond's outlet structures. For example, if the pond has a culvert and a weir structure and you want to redirect the weir flows off site, you can select the weir structure. Two hydrographs will be created; one, Divert-1, consisting of the weir flows; and the other, Divert-2, made from the remaining flows.

Click **[Compute]** when finished.



4.8 Batch Run

It's inevitable that once your basin model has been constructed, you'll need to make some changes. If you're making changes to any upstream hydrographs, those changes will need to be carried to any downstream hydrographs.



The Batch Run feature can do this for you in one click rather than recomputing each hydrograph. Another reason to use Batch Run is after making changes to the Precipitation Manager settings. For example, you activated or deactivated additional return periods or changed the Design Storm from a 6-hour to a 3 hour. Perhaps you selected a new Time Interval in the Settings.

This batch run function begins at Hydrograph No. 1 and works downstream automatically, recomputing each hydrograph, the same as you would do manually, step-by-step. To use this feature, click the **[Run]** button on the Ribbon Toolbar.

4.9 Project Settings

The Project Settings dialog allows you to specify a Project Title, Time Interval and a variety of other settings. To open, click the **[Settings]** button on the Ribbon Toolbar.

Settings are divided into three categories:

This Project Only - Settings affect the current project only.

User Defaults - Default values that are automatically used when you start a new project.

Autosave Files - Options to have rainfall files saved automatically when edited. When turned off, the default, you will be prompted to save these files when edited.

Hydrology Studio Settings	
▲ This Project Only	
Title	
Units	U.S. Customary ▼
Time Interval (min)	2 ▼
SCS Shape Factor	484
▲ User Defaults	
Time Interval (min)	2 ▼
n-value	0.013
Orifice Coefficient	0.60
Weir Coefficient	3.33
▲ Autosave Files	
I-D-F Curves	☐
Rainfall Precipitation	☐
Custom Design Storms	☐
Apply Reset Close	

Click the column headers to expand

Title

Enter a title for this project. This optional item will be shown on the Main Window as well as printed reports.

Units

Select US Customary or Metric. *(At the time of this writing, Metric was not yet an option.)*

Time Interval

The Time Interval is the time increment with which your hydrographs are computed. If set to 2 for example, each hydrograph will have ordinates computed every 2 minutes. Hydrology Studio reserves up to 2,880 ordinates for each hydrograph. Thus, when using a 2 minute time interval, a hydrograph can span 2,880 x 2 minutes or 96 hours or 4 days. This is ample time for the majority of urban drainage studies and is why 2 is the default. Selecting a higher time interval will result in fewer points and use fewer computing resources, namely computing time. As you will see, Hydrology Studio is very quick and even 1 minute is barely noticeable in terms of calculation time.

SCS Method Considerations

Without going into great detail regarding the SCS unit hydrograph theory, it should be noted that your Time Interval should not exceed 50% of the Time to Peak of the Unit Hydrograph. If more, the Unit Hydrograph will not be constructed with proper accuracy and will be reflected in the final runoff hydrograph. Hydrology Studio will warn you when such instances occur prompting you to use a smaller time interval.

Rational Method Considerations

It is highly recommended that you use a 1-minute Time Interval when using the Rational method. This prevents missing the peak Q if it would fall on an odd time increment.

SCS Shape Factor

The Shape Factor is a component of the SCS method which affects the temporal pattern or shape of the unit hydrograph. This factor is typically 484. Some local ordinances require different values. You can change it here.

4.10 Editing Your Model

Hydrology Studio allows you to delete, copy & paste any existing hydrograph.

Deleting

To delete any hydrograph, select it and then click the **[Delete]** button on the Ribbon Toolbar - Edit tab. You can also delete a range of hydrographs by selecting the icons while holding down the **[Shift]** key. You will be prompted before the actual deleting occurs to give you a chance to cancel.

When deleting a Diversion hydrograph, both Divert-1 and Divert-2 will be deleted.

Copy & Paste

You can copy any hydrograph by first selecting it and clicking the **[Copy]** button on the Ribbon Toolbar - Edit tab. Only one hydrograph can be copied at a time. A copied hydrograph can be pasted by clicking anywhere on the Basin Model canvas, or by selecting an unused row on the Table tab, and then clicking **[Paste]**.

The Copy function does not copy to the Clipboard, rather it copies the hydrograph number. Paste before deleting any Copied hydrograph.

Inserting

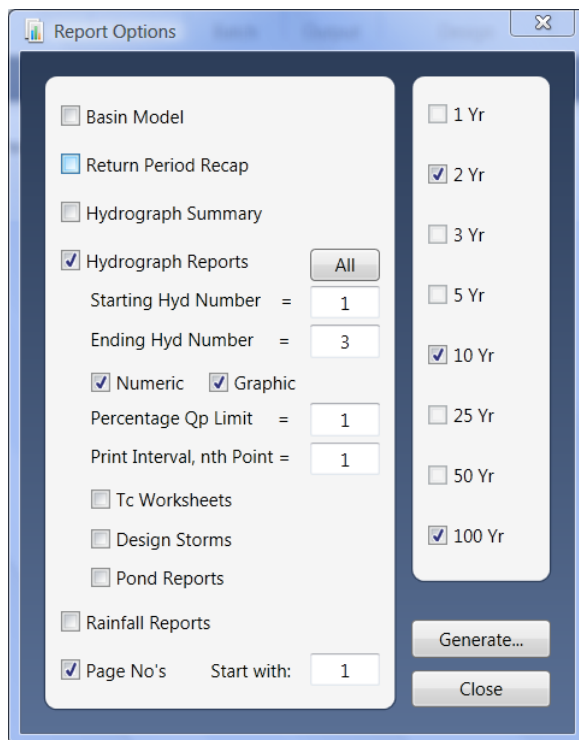
Sometimes you will find it necessary to insert a hydrograph into your basin model. To do this, simply select the hydrograph as the insertion point. For example, to insert a hydrograph between 3 and 4, select 4. Next, click **[Insert]** on the Ribbon Toolbar - Edit tab. The program will then push all downstream hydrographs down, leaving a blank hydrograph at the insertion point.

Repositioning

Once on the canvas you are free to move or reposition hydrograph icons to better match a real world layout. Simply click and drag with your mouse. You can also reposition groups of icons by holding down the **[shift]** key while dragging. All icons downstream of the selected icon will be included.

4.11 Printing Reports

A strong suite of Hydrology Studio is its reporting features. It provides several types and formats to choose from and can be printed at any time. There are no special preparations, procedures or prerequisites to meet. Just click on the **[Reports]** button and the following print menu appears:



To activate any of the options, simply click the corresponding option box.

Just pick & choose the types of reports you want and click **[Generate]**. That opens up the Document Viewer where you'll see a preview of your reports. From there you can send them to your printer for hard copies.

Report Options

If you're not sure what report types you like, feel free to explore by checking those items and reviewing them on the print preview. Although most options are self explanatory, below are some descriptions for clarity.

Starting & Ending Hydrograph Numbers - Use this to select a range of hydrographs to be printed. Enter the beginning and ending hydrograph numbers. Click the **[All]** button to quickly select all hydrographs within the basin model.

Numeric and Graphic - You can choose to have the reports contain a graphical and/or numerical output.

Percentage Qp Limit - This is useful for saving paper or just limiting the volume of numerical-based output. The reports will only include those Q's that are above this minimum setting. For example, a Qp Limit of 20 will limit the Q vs Time table to flow rates greater than $0.20 \times Q_p$. Note this only applies to the numerical output, not graphical.

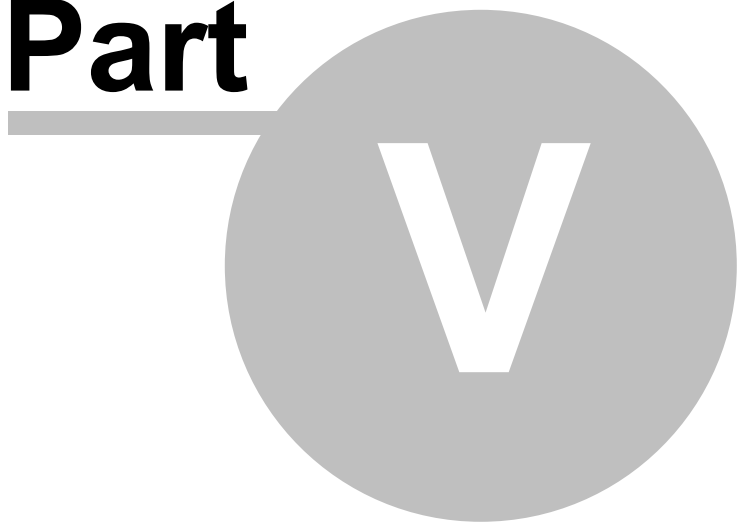
Print Interval, nth Point - This feature allows you to limit the numerical output by selecting to print every nth point on the hydrograph. For example, you may wish to print only every 4th ordinate on the hydrograph to save paper. If so, enter 4 for this item. Note however that printing at larger intervals can cause the report to miss the peak flow ordinate.

Page Numbers

To have each page of the total report set numbered, turn this option on. You can also specify the beginning page number. For example, you might want these printed pages to be included as an insert into another report starting on page number 15. In this case, enter 15 as the “Start with:” number.

Frequencies - The panel on the right allows you to choose which return periods to include. The inactive ones are disabled.

Part



5 Computational Methods

This section describes the computational methodologies employed by Hydrology Studio. It is highly recommended that you review the computational methods and equations used so that you will better understand the output and results. It is not the intention of this section to provide the basis of the theories used or to demonstrate how they were derived. But rather provide the actual equations and methods employed by Hydrology Studio.

Hydrology

The program uses only widely accepted methods within the industry. Namely HEC-22, Soil Conservation Service, SCS/NRCS and the Rational method. This section will provide a summary of the concepts used but it is not intended to be all-encompassing. Below is a list of publications which provide details on the methods used.

TR-20: Computer Program Manual 1992

TR-55: Urban Hydrology For Small Watersheds.

A Guide To Hydrologic Analysis Using SCS Methods, Richard McCuen

HEC No. 12; FHA; Drainage of Highway Pavements

HEC No. 22; FHA; Urban Drainage Design Manual

Hydrology for Engineers; Linsley, Kohler & Paulhus

NEH-4: Hydrology; Section 4, National Engineering Handbook

Urban Storm Drainage Management; Sheaffer, Wright, Taggart & Wright

Handbook of Hydraulics, Brater, King, Lindell, Wei

5.1 SCS Hydrographs

Hydrology Studio uses the SCS Unit Hydrograph Method for calculating SCS runoff hydrographs. This method is the same approach as used in TR-20. There are basically three steps involved:

1. Computing the SCS Unit Hydrograph
2. Computing an excess precipitation hyetograph from the design storm
3. Computing the final hydrograph using the concept of convolution

SCS Unit Hydrograph

A unit hydrograph is a hydrograph resulting from 1 inch of rainfall excess on a watershed over a given time interval. It is not the final runoff hydrograph but reflects the watershed characteristics. Once a unit hydrograph of a particular watershed is known, any design storm can be applied to it for computing the final runoff hydrograph. Many practicing civil engineers use the SCS 24-hour storms but keep in mind that any storm of any duration can be used with the unit hydrograph method. The Bulletin 71 Huff and the built-in Synthetic distributions are good examples and have

gained popularity over the years.

The unit hydrograph is constructed using the following methodology:

The peak discharge for the unit graph is computed as:

$$Q_p = \frac{484AQ}{T_p}$$

Where:

- Q_p = peak outflow (cfs)
- 484 = SCS Shape Factor
- A = area (sq. miles)
- Q = total excess precipitation (1 inch)
- T_p = time to peak (hrs)

The shape factor is a user-definable variable. The default value is set to 484 and creates a unit hydrograph that has 3/8 of its area under its rising limb. This factor is higher in mountainous watersheds, for example, 600, while in flat, sandy areas, will be lower, around 300. The Delmarva peninsula in Delaware uses 284.

The Time to Peak, T_p, and the Time Base, T_b, are what determines the characteristics of the unit hydrograph. These values are computed as follows:

$$T_p = \frac{T_c + D}{1.7}$$

Where:

- T_p = time to peak (hrs)
- T_c = time of concentration (hrs)
- D = time interval (hrs)
- T_c = 1.67 x Lag Time (L)

$$L = \frac{l^{0.8}(S+1)^{0.7}}{1900Y^{0.5}}$$

Where:

- L = lag time (hrs)
- l = hydraulic length (ft)
- S = (1000 / CN) - 10
- Y = basin slope (%)
- CN = SCS curve number

Time Base = 2.67T_p

Where:

T_b = time base (hrs)

T_p = time to peak (hrs)

It should be noted that the program will adjust the Time to Peak so that it coincides with the current Time Interval.

Excess Precipitation Hydrograph

An excess precipitation hyetograph (design storm) is needed in order to calculate the direct runoff hydrograph. Hydrology Studio offers several built-in design storms including those which you can customize. Most of which are the SCS 24-hr and 6-hr standard distributions. But other options include the IDF-based Synthetic Storms, Huff and as many as ten custom storms that you input directly. See also [Design Storms](#).

SCS 24-Hour Distributions

This hydrology software provides the full library of SCS 24-hr as well as the 6-hour standard dimensionless distributions. The incremental rainfall amounts for the 24-hour storms are computed from a polynomial equation which uses coefficients that vary throughout the storm. The equation is of the form:

$$P_t = C_0 + C_1T + C_2T^2 + C_3T^3$$

Where:

P_t = fraction of 24-hour precipitation

T = elapsed time (hrs)

C₀ = coefficient

C₁ = coefficient

C₂ = coefficient

C₃ = coefficient

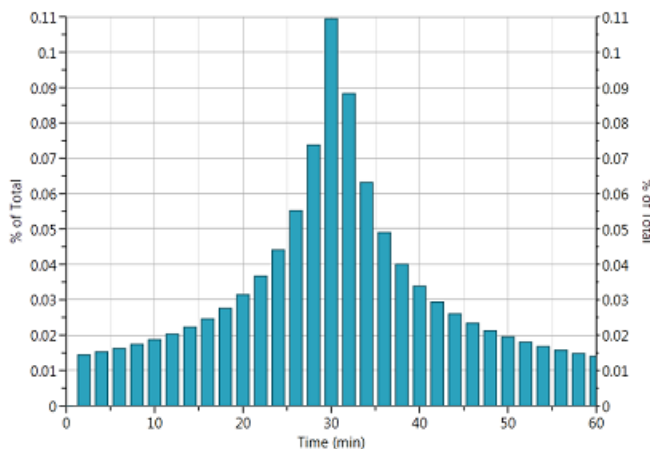
The list of coefficients for each distribution may be obtained from the NRCS.

Synthetic Storms

This option can actually produce an infinite number of design storm hyetographs but for practical reasons, Hydrology Studio limits them to 1, 2, 3, 6, 12 and 24-hour durations. The program uses the rainfall IDF curves to compute depth increments over the time intervals. From this the design storm is constructed by placing the maximum depth increment near the center of the storm and arranging the other increments in a symmetrical alternating form. This is the same method used by the SCS years ago to

construct their 24-hour storms.

There's much debate about the usefulness of a 24-hour storm applied to a small urban-like site with T_c 's as low as 15 minutes. The Synthetic Storm offers a good solution in that it can be matched to the site, that is, its total duration can be specified so that it better fits the computed T_c . For example, if T_c is 20 minutes, you could specify a one-hour storm rather than deal with a 24-hr storm. The one-hour storm lasts long enough so that the entire drainage area contributes to flow to the most downstream point. Going beyond T_c only adds unnecessary volume and calculation resources.



The Synthetic storm is an excellent alternative to 24-hour distributions

Regardless of which distribution you are using, including the SCS, Synthetic, Huff and the Custom storms directly input, the precipitation increments are converted to excess precipitation. This is where the Curve Number comes in and determines how much of the actual rain is converted into runoff or excess. The following equation is used:

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

Where:

- Q = excess volume of precipitation (in)
- P = accumulated precipitation (in)
- S = potential maximum retention
= $(1000 / CN) - 10$
- CN = SCS curve number

The computed volumes are then converted to excess increments used for the final

excess precipitation hyetograph.

Computing the Final Hydrograph

Hydrology Studio computes SCS Method runoff hydrographs by convoluting a rainfall hyetograph through a unit hydrograph. This method is known as linear superpositioning, and means that each ordinate of the rainfall hyetograph is multiplied by each ordinate of the unit hydrograph, thus creating a series of smaller hydrographs. These hydrographs are then summed to form the final runoff hydrograph.

5.2 Rational Method Hydrographs

The Rational method was developed over 100 years ago and continues to be used for urban watershed modeling, typically on areas less than about 20 acres. Hydrology Studio can generate two kinds of Rational Method hydrographs;

1. Standard Rational
2. Modified Rational

Standard Rational

The Standard Rational Method hydrograph is shaped like an isosceles triangle. The Peak is equivalent to the peak discharge as determined by the well known Rational formula.

$$Q_p = CiA \times C_f$$

Where:

Q_p = hydrograph peak discharge (cfs)

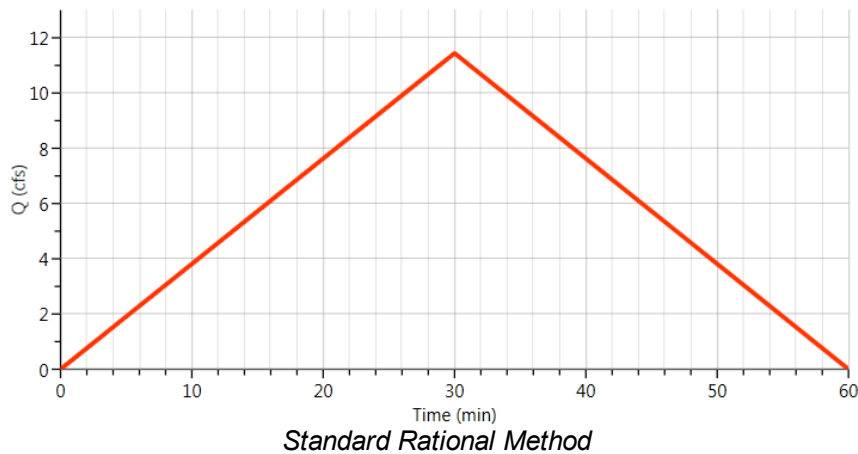
C = runoff coefficient

A = basin area (ac)

i = intensity (in/hr)

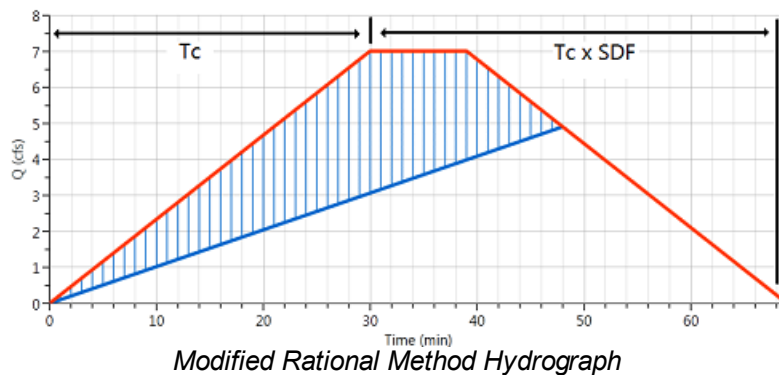
C_f = frequency correction factor

The time-to-peak of the hydrograph is equal to the time of concentration. The ascending limb is equal to the time-to-Peak x (Ascending Limb Factor, ALF). The receding limb of the hydrograph is equal to the time-to-peak x (Receding Limb Factor, RLF). The hydrograph is an isosceles triangle when ALF = 1 and RLF = 1. Intermediate hydrograph values are computed using straight-line interpolation.



Modified Rational

This method modifies the Standard Rational method. The runoff hydrograph is assumed to be trapezoidal in shape with a peak runoff rate calculated using the rational formula described above. Hydrology Studio finds the Storm Duration Factor (SDF) which maximizes the required storage of an anticipated detention pond routing.



5.3 Time of Concentration

In addition to manual entry, Hydrology Studio computes Time of Concentration using one of three methods, Lag, Kirpich and TR55.

Lag method

This is the TR-20 default method where:

$$T_c = 1.67L$$

$$L = \frac{l^{0.8}(S+1)^{0.7}}{1900Y^{0.5}}$$

Where:

- L = lag time (hrs)
- l = hydraulic length
- S = (1000 / CN) - 10
- Y = basin slope (%)
- CN = SCS curve number

Kirpich method

Generally used for natural basins with well defined routes for overland flow along bare earth or mowed grass roadside channels. It is similar to the Lag method but will give shorter times compared to the Lag method.

$$T_c = 0.0078L^{0.77}S^{-0.385}$$

Where:

- T_c = time of concentration (min)
- L = hydraulic length (ft)
- S = average basin slope (ft/ft)

TR-55 method

T_c is broken into 3-components or segments as prescribed by TR55. The final T_c is the sum total of the three components.

$$T_c = T_{Sheet} + T_{Shallow} + T_{Channel}$$

Sheet Flow Time

Flow over plane surfaces and typically ranges between 125 to 150 feet.

$$T_{sheet} = \frac{0.007(nL)^{0.8}}{P_2^{0.5}S^{0.4}}$$

Where:

- n = Manning's roughness coefficient
- L = Flow Length (must be ≤ 300 ft per TR55, ≤ 100 ft per WinTR55)
- P₂ = Two-year 24-hr rainfall (in)

S = Land Slope (ft/ft) (Entered as % in the program)

Shallow Concentrated Flow Time

After about 300 feet, sheet flow become shallow concentrated flow. Please note that over very uniform surfaces, this maximum becomes 150 feet.

$$T_{\text{shallow}} = \frac{L}{3600V}$$

Where:

L = Flow Length (ft)

V = Average velocity (ft/s) and

$$V = C_p \sqrt{S}$$

Where:

- C_p = 20.3282 paved surfaces
- C_p = 16.1345 unpaved surfaces
- S = Watercourse slope (ft/ft)

Channel Flow Time

Occurs within channels, swales, ditches, streams or even piped systems. Manning's equation is used to compute velocity.

$$T_{\text{channel}} = \frac{L}{3600V}$$

Where:

L = Flow length (ft)

V = Average velocity (ft/s) and

$$V = \frac{1.49 R^{2/3} S^{0.5}}{n}$$

Where:

V = Average velocity (ft/s)

R = Hydraulic radius (ft) = a/wp

S Channel slope (ft/ft) (Entered as % in the program)

n = Manning's roughness coefficient

5.4 Combining Hydrographs

When adding hydrographs at junctions Hydrology Studio computes the algebraic sum of each hydrograph ordinate, starting at each hydrograph time = 0, to derive the final hydrograph. This procedure takes in account the individual lag times from each hydrograph.

5.5 Channel Reach Routing

Hydrology Studio employs the Modified Att-Kin (Attenuation Kinematic) and the Muskingum-Cunge methodologies for channel reach routing. Both theories are based on a discharge-flow area relationship where:

$$Q = xA^m$$

The equations and formulas used to compute x and m are further described in Technical Release 20. Hydrology Studio allows you to optionally directly enter these variables when using the Modified Att-Kin method.

Modified Att-Kin

The Modified Att-Kin method's procedures are as follows:

$$O_{t+dt} = (1-C) \times O_t + C \times I_t$$

Where:

O_{t+dt} = outflow at time $t+dt$

O_t = outflow at time t

I_t = inflow at time t

C = routing coefficient

The routing coefficient is computed as:

$$C = \frac{(2dt)}{2K + dt}$$

Where:

dt = time interval in seconds or hours

$K = L/(mV)$

Where:

L = channel reach length (ft)

m = factor relating average velocity and wave velocity (celerity)

V = average velocity (ft/s)

Muskingum-Cunge

The Muskingum-Cunge routing procedure has been incorporated into the NRCS TR20 hydrologic model. It will typically give higher peak flows than the Modified Att-Kin method. Both methods are more appropriate for modeling long channels.

Muskingum-Cunge computes outflows using four primary coefficients as shown in the following equation:

$$O_2 = C_1 I_1 + C_2 I_2 + C_3 O_1$$

Where:

O_2 = Outflow discharge at time 2

O_1 = Outflow discharge at time 1

$$C_1 = \frac{\left[\left(\frac{dt}{K}\right) + 2X\right]}{C_0}$$

$$C_2 = \frac{\left[\left(\frac{dt}{K}\right) - 2X\right]}{C_0}$$

$$C_3 = \frac{\left[2(1 - X) - \frac{dt}{K}\right]}{C_0}$$

$$C_0 = \left(\frac{dt}{K}\right) + 2(1 - X)$$

Where:

dt = time interval in seconds

K & X are constants determined from:

$$K = \frac{L}{mV_0}$$

Where:

L = length of the channel reach

m = factor relating average velocity and wave velocity (celerity)

V_0 = average velocity

$$X = 0.5 \left[1 - \frac{Q}{T_0 S_0 m V_0 L} \right]$$

Where:

Q = peak inflow

T_0 = top width at Q

S_0 = longitudinal slope

5.6 Stage-Storage

Stage Storage calculations use the procedures below based on the storage type selected.

Contours

Hydrology Studio uses either the average-end-area method applied vertically or the Conic method. The Conic method uses this equation:

$$V = d \left(\frac{A_1 + \sqrt{A_1 A_2} + A_2}{3} \right)$$

Where:

V = storage

d = change in elevation between points 1 and 2

A_1 = surface area at elevation 1

A_2 = surface area at elevation 2

Trapezoid

Trapezoidal shaped ponds are computed by:

$$V = LWD + (L + W)Z D^2 + \frac{4}{3} Z^2 D^3$$

Where: V = storage volume at stage D

D = stage or depth

L = bottom length

W = bottom width

Z = side slope, (Z:1) (horizontal to 1-vertical)

Underground Chambers

Volume of a chamber pipe is computed by:

$$V = \frac{L}{6} (A_1 + 4M + A_2)$$

Where:

V = storage volume

L = pipe length

A₁ = cross-sectional area of depth at downstream end

A₂ = cross-sectional area of depth at upstream end

M = cross-sectional area of depth at midsection

When the pipe slope equals zero, Volume = L x A₁

5.7 Stage Discharge

Outlet structure discharges are treated as a function of the water surface elevation in the pond. The procedures described below are divided into two categories; Culverts & Orifices and Weirs.

Unless the multi-stage option is not checked, each outlet structure is treated independently. This option allows you to put structures in series, thereby creating a multi-stage structure. This causes the outflows from that device to route through the Culvert. The structure with the least capacity at any given stage controls the outflow at that stage. The Culvert is always the final outflow device so it does not have a multi-stage option.

Culverts & Orifices

Culverts and orifices are computed under both inlet and outlet control conditions. The discharge equation used for culverts and orifices is:

$$Q = C_o A \sqrt{\frac{2gh}{k}} \times Nb$$

Inlet Control

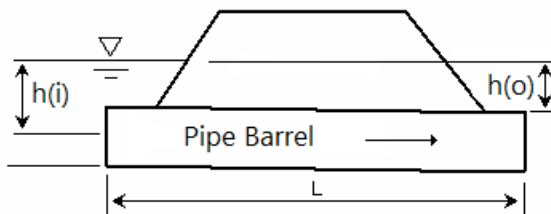
Q = discharge (cfs)
 A = culvert area (sqft)
 h = distance between the inlet water surface and the centroid of the culvert barrel (1/2 flow depth during partial flow) (ft)
 N_b = number of barrels
 Co = orifice coefficient
 $k = 1$

Outlet Control

Q = discharge (cfs)
 A = culvert area (sqft)
 h = distance between the upstream and downstream water surface
 N_b = Number of barrels
 $Co = 1$
 $k = 1.5 + [(29n^2L)/R^{1.33}]$

Where:

n = Manning's n-value
 L = culvert length (ft)
 R = area/wetted perimeter (ft)



$h(i)$ = inlet control head. $h(o)$ = outlet control head.

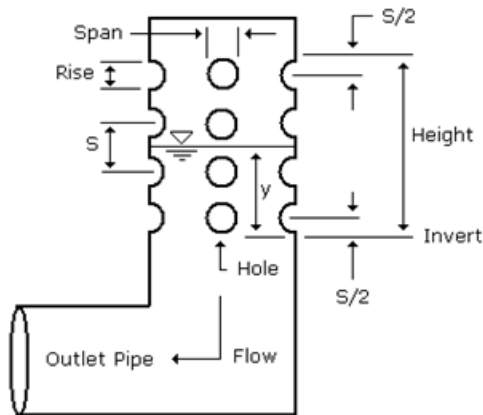
During the calculation process, both inlet and outlet control are evaluated. Under inlet control, the discharge depends on the barrel shape, cross-sectional area of the pipe and inlet edge. Under outlet control, the discharge depends on the slope, length and roughness of the barrel. Under outlet control, flow can enter the structure at a faster rate than it can exit. Under Inlet control, it's harder for water to enter the pipe than exit.

Tailwater

When a tailwater (T_w) elevation has been entered, it is compared the pond stage and computes a tailwater head, h_{TW} . If this head is less than the head computed as above (h), then $h = h_{TW}$.

Perforated Riser

This is a special kind of orifice structure as shown above which contains a series of same-sized holes all within a vertical height.



The following formula by McEnroe, 1988 is used to estimate the outflow.

$$Q = C_p \frac{2A}{3H_s} \sqrt{2g} H^{3/2}$$

Where:

Q = discharge (cfs)

$C_p = 0.61$

A = cross-sectional area of all the holes (sqft)

H_s = height (ft)

Weirs

Hydrology Studio uses a standard weir equation for **Rectangular, Compound, Cipoletti, Broad Crested & Riser** structures.

$$Q = C_w L H^{1.5}$$

Where:

Q = discharge over weir (cfs)

L = length of the weir crest (ft)

H = distance between water surface and the crest (ft)

C_w = weir coefficient, typically 3.33

V-notch

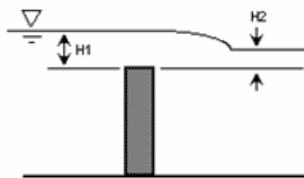
V-notch weirs are computed using this equation:

$$Q = 2.54 \tan\left(\frac{\theta}{2}\right) H^{2.5}$$

Where: Q = discharge over weir (cfs)
 θ = angle of v-notch (degrees)
 H = head on apex of v-notch (ft)

Adjustment for Submerged Weirs

Rectangular, V-notch & Cipoletti weirs can be affected by submergence, i.e., when the tailwater rises above the weir's crest. This typically occurs in multi-stage structures when the head produced by the Culvert is higher than the pond water surface, thus reducing the discharge.



Submerged Weir

The equation for the reduction in flow is:

$$Q_s = Q_r \left(1 - \left(\frac{H_2}{H_1} \right)^{1.5} \right)^{0.385}$$

Where:
 Q_s = submerged flow (cfs)
 Q_r = unsubmerged flow from standard weir equations
 H₁ = upstream head above crest (ft)
 H₂ = downstream head above crest (ft)

An “s” is added as a suffix to numbers displayed in the Stage-Discharge table to indicate when flows have been adjusted for submergence.

5.7.1 Exfiltration

Exfiltration is a term used by Hydrology Studio indicating flow exits the pond. It can be used interchangeably with *infiltration*. Exfiltration flows are computed using the following equation:

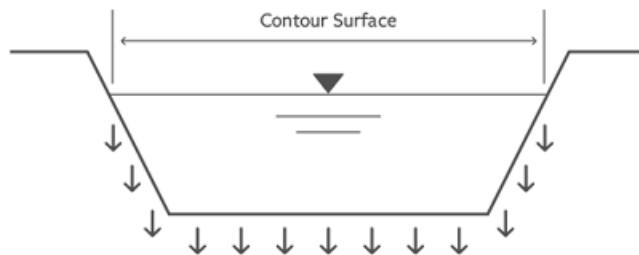
$$Q_{ex} = \left(\frac{ER \times SA}{12 \times 3600} \right)$$

Where:

Q_{ex} = outflow (cfs)

ER = exfiltration (percolation) rate (in/hr)

SA = contour surface area (sqft)



Exfiltration is applied to contour surface areas

5.7.2 Drawdown

Often times your detention pond designs will involve extended detention times. Typical requirements can be met by providing a 24-hour drawdown time for a portion of a water quality volume. Hydrology Studio automatically computes drawdown times for each pond and tabulates it on the Stage-Storage-Discharge Table. Draw down times are computed at each stage using the following equation.

$$Time = \frac{dStor}{Q_{ave}}$$

Where:

Time = incremental drawdown time from Stage_n to Stage_{n-1}

$dStor$ = change in storage from Stage_n to Stage_{n-1}

Q_{ave} = average outflow from Stage_n to Stage_{n-1}

As shown in the table below, it would take 3.49 hours for the pond to drawdown from Stage 0.35.

	Stage (ft)	Elev (ft)	Storage (cuft)	Total Q (cfs)	Drawdown (hrs)
	0.00	1000.00	0.000	0.00	0.00
	0.04	1000.04	33.0	0.001	0.00
	0.07	1000.07	66.0	0.006	0.00
	0.11	1000.11	99.0	0.013	0.00
	0.14	1000.14	132	0.022	2.04
	0.18	1000.18	165	0.030	2.39
	0.21	1000.21	198	0.036	2.67
	0.25	1000.25	231	0.041	2.91
	0.28	1000.28	264	0.045	3.12
	0.32	1000.32	297	0.049	3.31
	0.35	1000.35	330	0.053	3.49

5.8 Pond Routings

Probably the most widely used method of determining the required storage volume in detention basins is the Storage-Indication Method and is the method used by Hydrology Studio. This routing procedure consists of a trial and error process based upon the Continuity Equation. The basic premise is that, over a given time interval, the volume of water entering the pond minus the volume of water leaving the pond equals the required storage volume. In simpler terms, what goes in minus what goes out is what's left over... storage.

The method begins with a stage-storage-discharge relationship (a pond you developed in the program), an inflow hydrograph and the following relationship:

$$I - O = \frac{ds}{dt}$$

Where:

I = inflow

O = outflow

ds/dt = change in storage

Part

VI

6 Useful Tables

6.1 SCS Curve Numbers

Land Use Description	Hydrologic Soil Group			
Residential	A	B	C	D
<i>Average Lot Size</i>				
1/8 acre or less	77	85	90	92
1/4 acre	61	75	83	87
1/3 acre	57	72	81	86
1/2 acre	54	70	80	85
1 acre	51	68	79	84
2 acre	46	65	77	82
Paved parking, roofs	98	98	98	98
Streets and Roads				
Paved with curbs	98	98	98	98
Gravel	76	85	89	91
Dirt	72	82	87	89
Commercial and business areas	89	92	94	95
Industrial districts	81	88	91	93
Open spaces, lawns, parks				
good condition	39	61	74	80
fair condition	49	69	79	84
Fallow	77	86	91	94
Row Crops	72	81	88	91

Source: Soil Conservation Service TR-55

6.2 Runoff Coefficients

Description of Area	Coefficient	Typical Design
Business		
Downtown	0.70 - 0.95	
Neighborhood	0.50 - 0.70	
Residential		
Single family	0.35 - 0.45	
Multi-units detached	0.40 - 0.75	
Suburban	0.25 - 0.40	
Apartments	0.50 - 0.70	
Industrial		
Light	0.50 - 0.80	
Heavy	0.60 - 0.90	
Parks, cemeteries	0.10 - 0.25	
Playgrounds	0.20 - 0.35	
Railroad yards	0.20 - 0.40	
Lawns		
Sandy soil	0.05 - 0.20	
Heavy soil	0.18 - 0.35	0.30
Unimproved	0.10 - 0.30	0.30
Asphalt	0.70 - 0.95	0.90
Concrete	0.80 - 0.95	0.90
Roofs	0.75 - 0.95	0.90

Source: ASCE

6.3 Manning's n-values

Material	Manning's n
Pipes	
Reinforced concrete	0.013
Vitrified clay pipe	0.013
Smooth welded pipe	0.011
Corrugated metal pipe	0.023
Polyvinyl chloride (PVC)	0.010
Natural Channels	
Gravel beds, Straight	0.025
Gravel beds, large boulders	0.040
Earth, straight, some grass	0.026
Earth, winding, no vegetation	0.030
Earth, winding	0.050
Overland Flow	
Smooth surfaces, concrete, asphalt, bare soil	0.011
Fallow	0.05
Cultivated soils, residue $\leq 20\%$	0.06
Cultivated soils, residue $> 20\%$	0.17
Short grass	0.15
Dense grass	0.24
Bermuda grass	0.41
Light underbrush woods	0.40
Dense underbrush woods	0.80

Source: Soil Conservation Service TR55

Part

VII

7 End User License Agreement

EULA stands for **End User Licensing Agreement**. This is the agreement through which the software is licensed to the software user.

EULA

END-USER LICENSE AGREEMENT FOR HYDROLOGY STUDIO. IMPORTANT. PLEASE READ THE TERMS AND CONDITIONS OF THIS LICENSE AGREEMENT CAREFULLY BEFORE CONTINUING WITH THIS PROGRAM INSTALL: Hydrology Studio End-User License Agreement ("EULA") is a legal agreement between you, THE BUYER, and Hydrology Studio. By installing, copying, or otherwise using the SOFTWARE PRODUCT, you agree to be bound by the terms of this EULA. This license agreement represents the entire agreement concerning the program between THE BUYER and Hydrology Studio, and it supersedes any prior proposal, representation, or understanding between the parties. If you do not agree to the terms of this EULA, do not install or use the SOFTWARE PRODUCT.

The SOFTWARE PRODUCT is protected by copyright laws and international copyright treaties, as well as other intellectual property laws and treaties. The SOFTWARE PRODUCT is licensed, not sold.

1. GRANT OF LICENSE

THIS SOFTWARE PRODUCT IS COPYRIGHTED AND ALL RIGHTS ARE RESERVED BY HYDROLOGY STUDIO. THE DISTRIBUTION AND SALE OF THIS PRODUCT ARE INTENDED FOR USE OF THE ORIGINAL PURCHASER ONLY. YOU MAY INSTALL AND USE ONE COPY OF THE SOFTWARE ON A SINGLE COMPUTER. THE PRIMARY USER OF THE COMPUTER ON WHICH THE SOFTWARE IS INSTALLED MAY MAKE A SECOND COPY FOR HIS OR HER EXCLUSIVE USE ON A PORTABLE COMPUTER. YOU MAY ALSO INSTALL A COPY ON A NETWORK SERVER, USED ONLY TO RUN THE SOFTWARE; HOWEVER, YOU MUST ACQUIRE AND DEDICATE A LICENSE FOR EACH SEPARATE COMPUTER ON WHICH THE SOFTWARE IS INSTALLED OR RUN FROM THE STORAGE DEVICE. EXCEPT AS PROVIDED HEREIN, A LICENSE FOR THE SOFTWARE MAY NOT BE SHARED OR USED CONCURRENTLY ON DIFFERENT COMPUTERS.

2. COPYRIGHT

All title, including but not limited to copyrights, in and to the SOFTWARE PRODUCT and any copies thereof are owned by Hydrology Studio or its suppliers. All title and intellectual property rights in and to the content which may be accessed through use of the SOFTWARE PRODUCT is the property of the respective content owner and may be protected by applicable copyright or other intellectual property laws and treaties. This EULA grants you no rights to use such content. All rights not expressly granted are reserved by Hydrology Studio.

3. NO WARRANTIES

Hydrology Studio expressly disclaims any warranty for the SOFTWARE PRODUCT. The SOFTWARE PRODUCT is provided 'As Is' without any express or implied warranty of any kind, including but not limited to any warranties of merchantability or fitness of a particular purpose. Hydrology Studio does not warrant or assume responsibility for the accuracy or completeness of any information, text, graphics, links or other items contained within the SOFTWARE PRODUCT.

4. LIMITATION OF LIABILITY

In no event shall Hydrology Studio be liable for any damages (including, without limitation, lost profits, business interruption, or lost information) rising out of 'Authorized Users' use of or inability to use the SOFTWARE PRODUCT, even if Hydrology Studio has been advised of the possibility of such damages. In no event will Hydrology Studio be liable for loss of data or for indirect, special, incidental, consequential (including lost profit), or other damages based in contract, tort or otherwise. Hydrology Studio shall have no liability with respect to the content of the SOFTWARE PRODUCT or any part thereof, including but not limited to errors or omissions contained therein, trademark rights or business interruption.

Copyright © 2013 Hydrology Studio
All Rights Reserved

Index

- A -

Activate
 Design Storms 58
 Return periods 58
 Activating the software 6
 Adding hydrographs 74

- B -

Background Map 12
 Batch Computing 26
 Batch Run 103

- C -

Channel Flow 71
 Channel Routing 75
 Charts
 export 14
 save 14
 CN 128
 Copy 105
 Correction Factor 114
 Correction Factors 57
 Curve Numbers 128
 Custom Design Storms 63

- D -

Delete 105
 Design storm 58
 Design Storms
 Activating 62
 Viewing 62
 Detention Pond 78
 Drawdown 125

- E -

exfiltration 125
 Export
 charts 46

grids 46

- H -

Hydro-35 51
 Hydrology Software 5

- I -

IDF Curve Equation 55
 IDF curves 49
 Import rainfall intensities 53
 Importing Custom Storms 65
 infiltration 125
 Insert 105
 Installing 6

- K -

Kirpich 115

- L -

Lag method 115

- M -

Manning's n values 130
 Manual entry hydrograph 72
 Manual storage 85
 Modified Att-Kin 118
 Modified Rational 114
 Modified Rational hydrograph 69
 Muskingum-Cunge 118

- P -

Paste 105
 perforated riser 121
 Pond outlets 89
 Post-development 27
 Precipitation 48
 Pre-development 27
 Printing 44
 Project
 Settings 10

Project
 Starting New 10
Project Settings
 Title 104
 Units 104

- R -

Rainfall 48
Rainfall precipitation 58
Rational hydrograph 69
Rational method 27
Reports 44
Runoff Coefficients 129

- S -

SCS Hydrograph 68
SDF 114
Settings 10
Shallow Concentrated Flow 71
Shape Factor 104
 Delmarva 110
Sheet Flow 71
Standard Rational 114
Storage estimate 33
Storage indication 126
Storm Duration Factor 114
Surface Chart 88
Synthetic Storms 110

- T -

Third-degree Polynomial 55
Time Interval 104
TR55
 Channel flow 115
 Shallow Concentrated flow 115
 Sheet flow 115
Trial Route 37
 How to use 92
Tutorials 18

- U -

Underground chambers 86, 120
Unit hydrograph 110

Updates 7

- W -

Watershed Modeling 19
weir
 calculations 121
 submerged 121
 v-notch 121

- Z -

Zoom 14

Endnotes 2... (after index)

Back Cover